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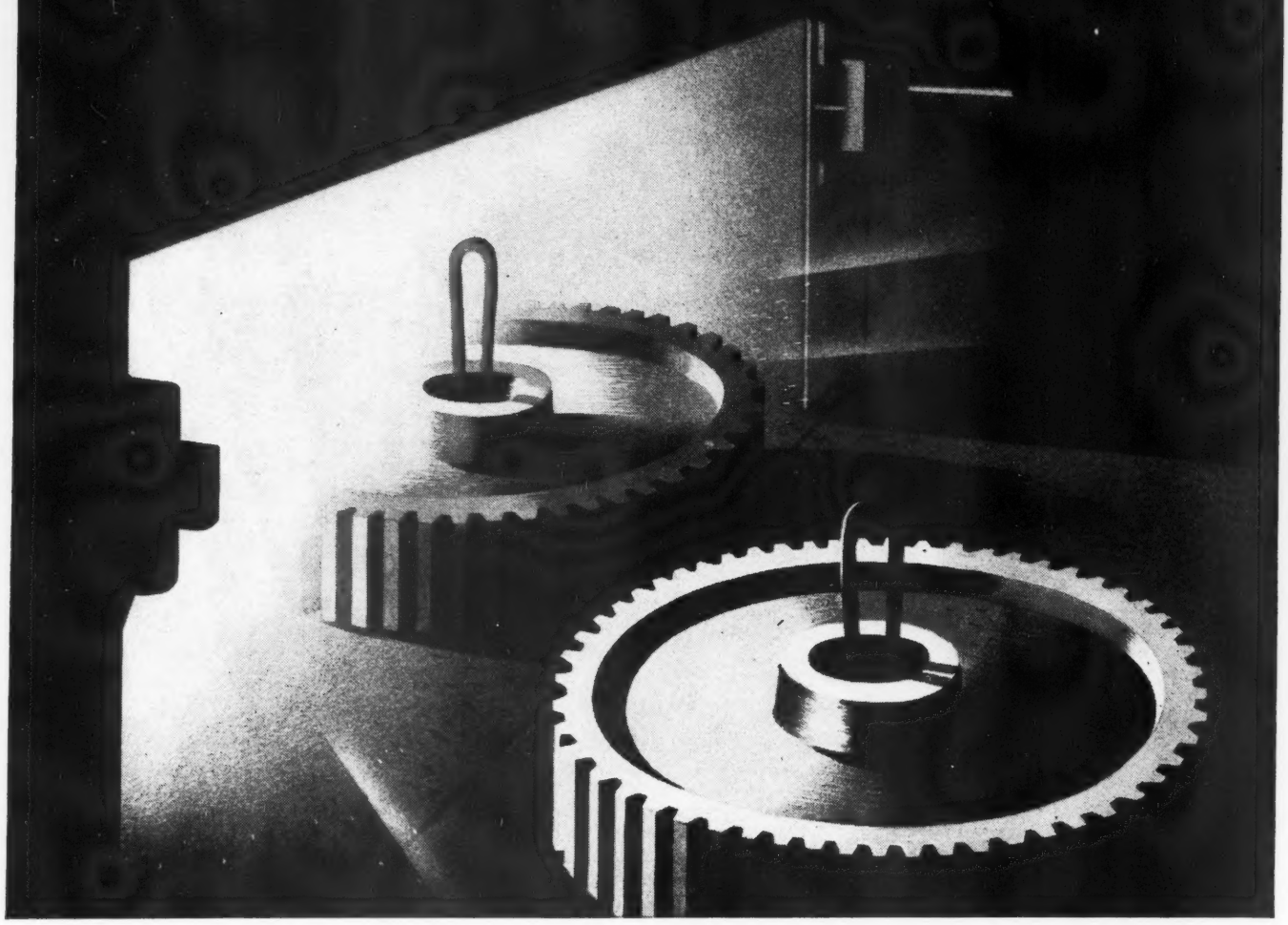
Molybdenum steels require relatively high tempering temperatures and therefore are relatively free from internal stresses.



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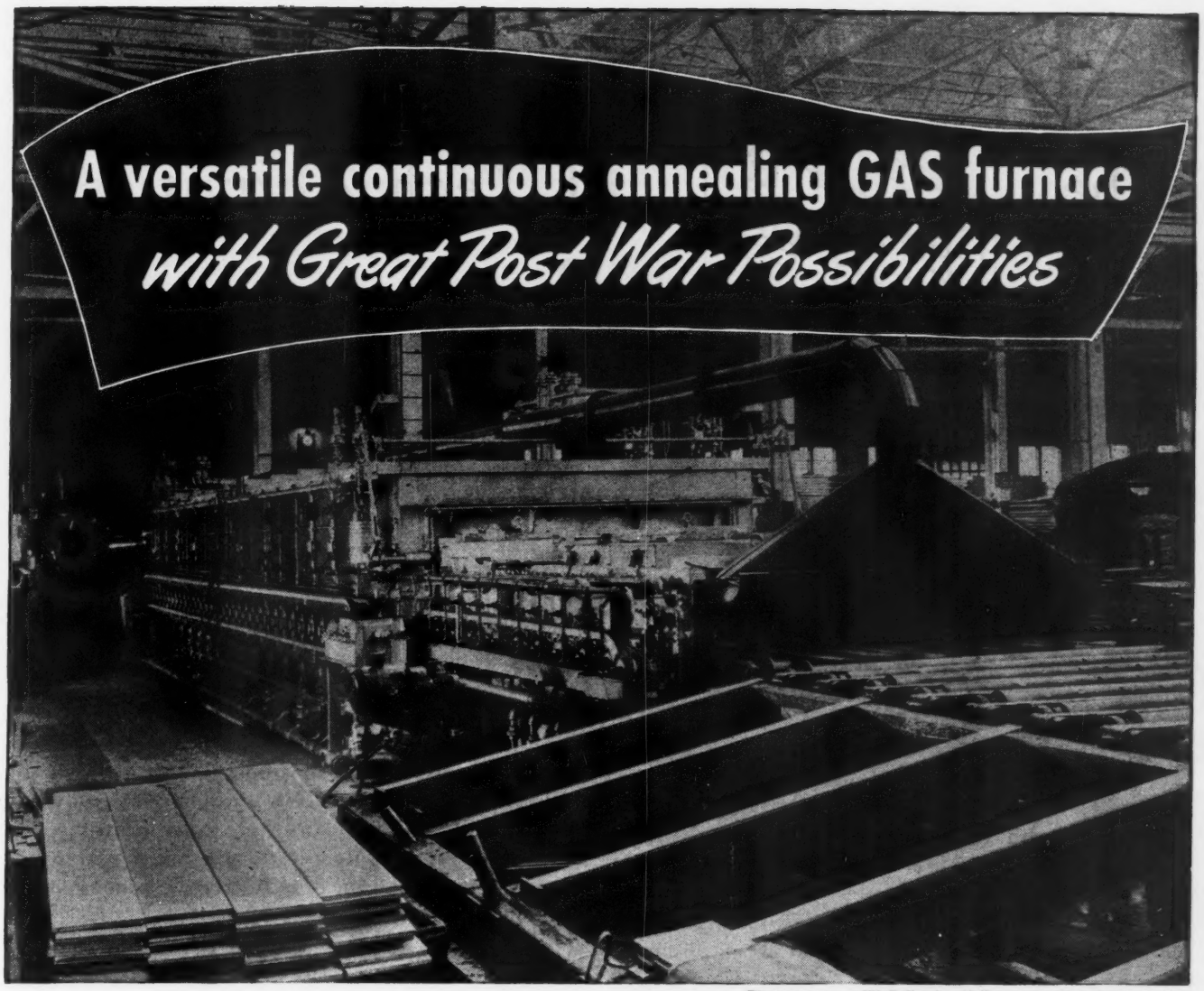

Photo courtesy W. S. Rockwell Company, New York, N. Y.

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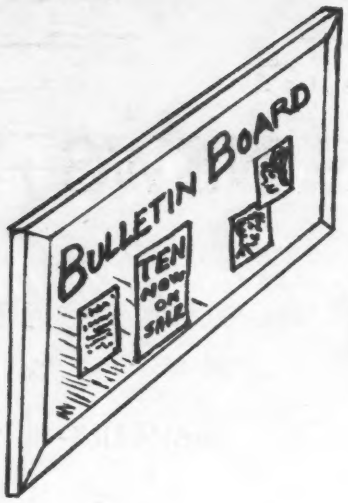
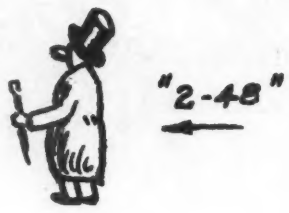
The  of Tech Activities



News of the Student Professional Societies of M. I. T.

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One More Volume . . .

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S-2 STEAM LOCOMOTIVE

Courtesy Pennsylvania Railroad

TITLE PAGE

LOOKING TOWARD THE BOW OF THE PARTIALLY COMPLETED "HINDENBURG"

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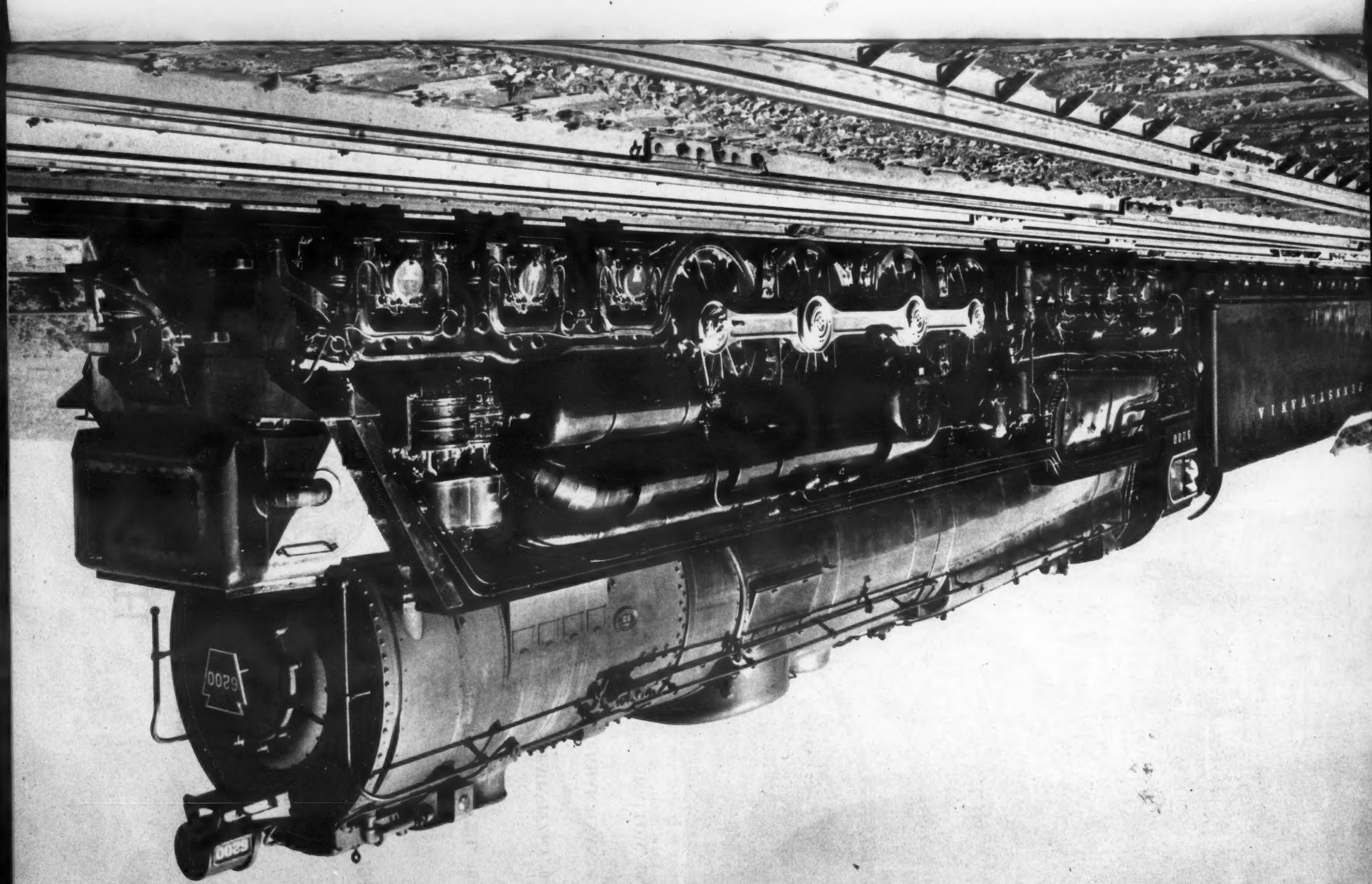
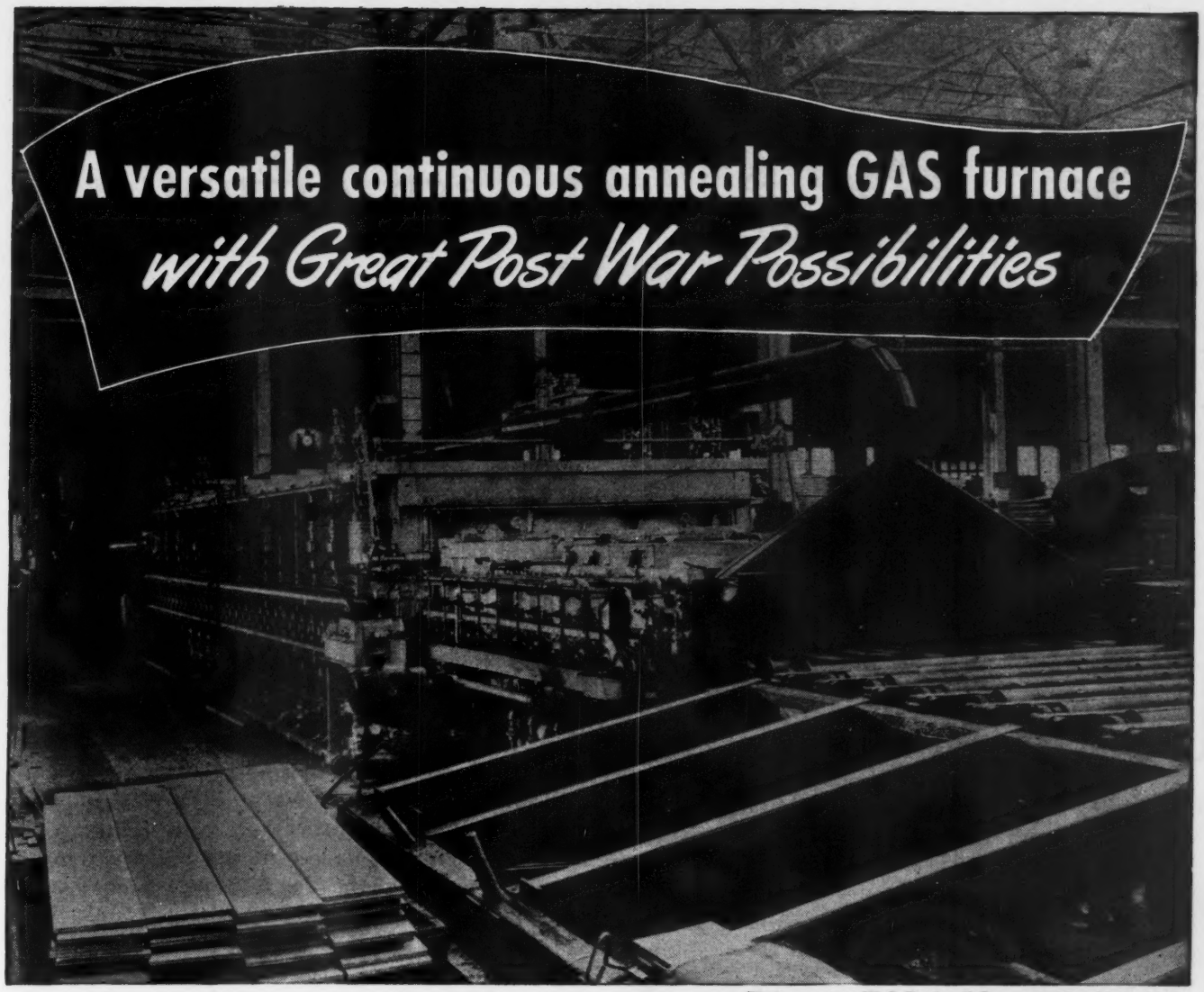
Published monthly throughout the school year, at Walker Memorial, Cambridge 39, Massachusetts, by the undergraduates of the Massachusetts Institute of Technology. Entered as second class matter, at the Post Office, June 1, 1920, at Boston, Mass., under the Act of March 3, 1879. Copyright 1944 by The Tech Engineering News. Subscription per year $1.50. Foreign $1.75. One copy 25 cents.





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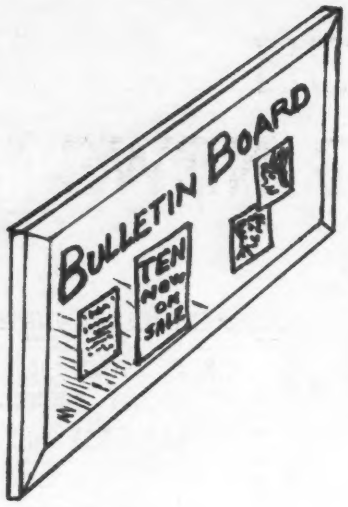
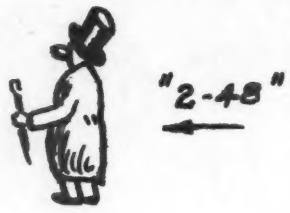
The  of Tech Activities



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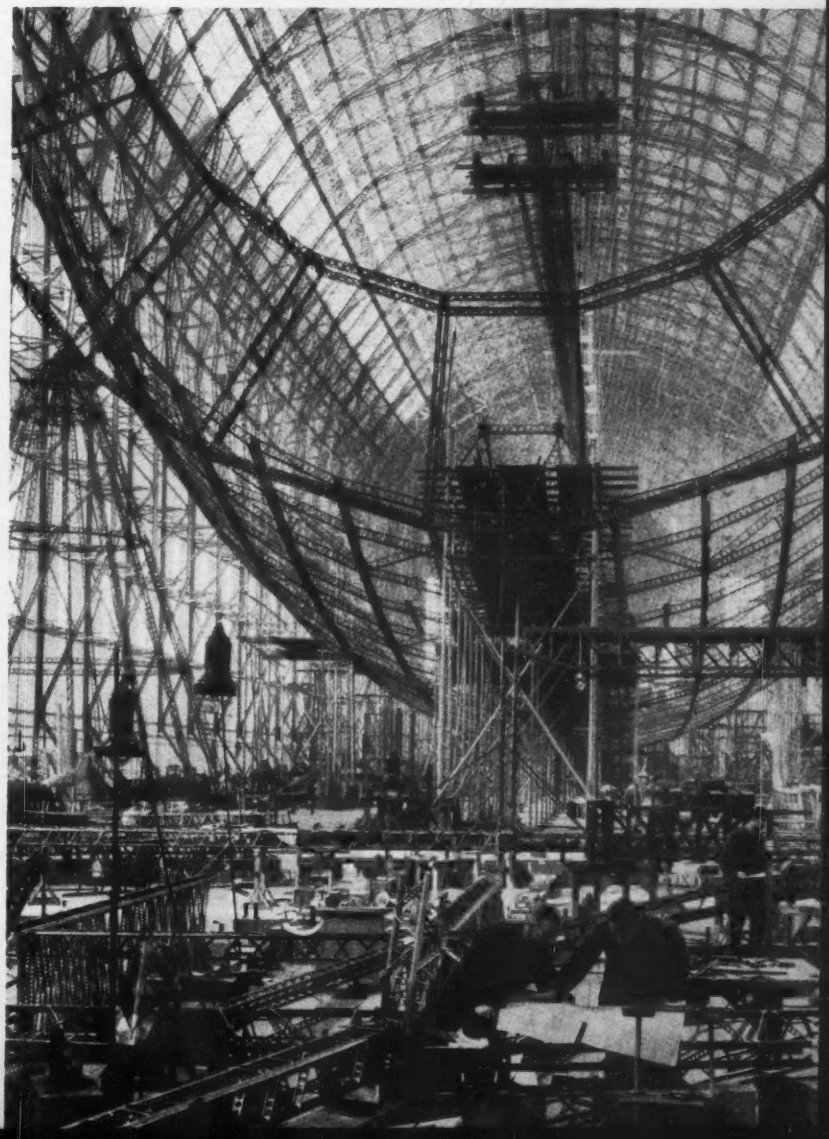

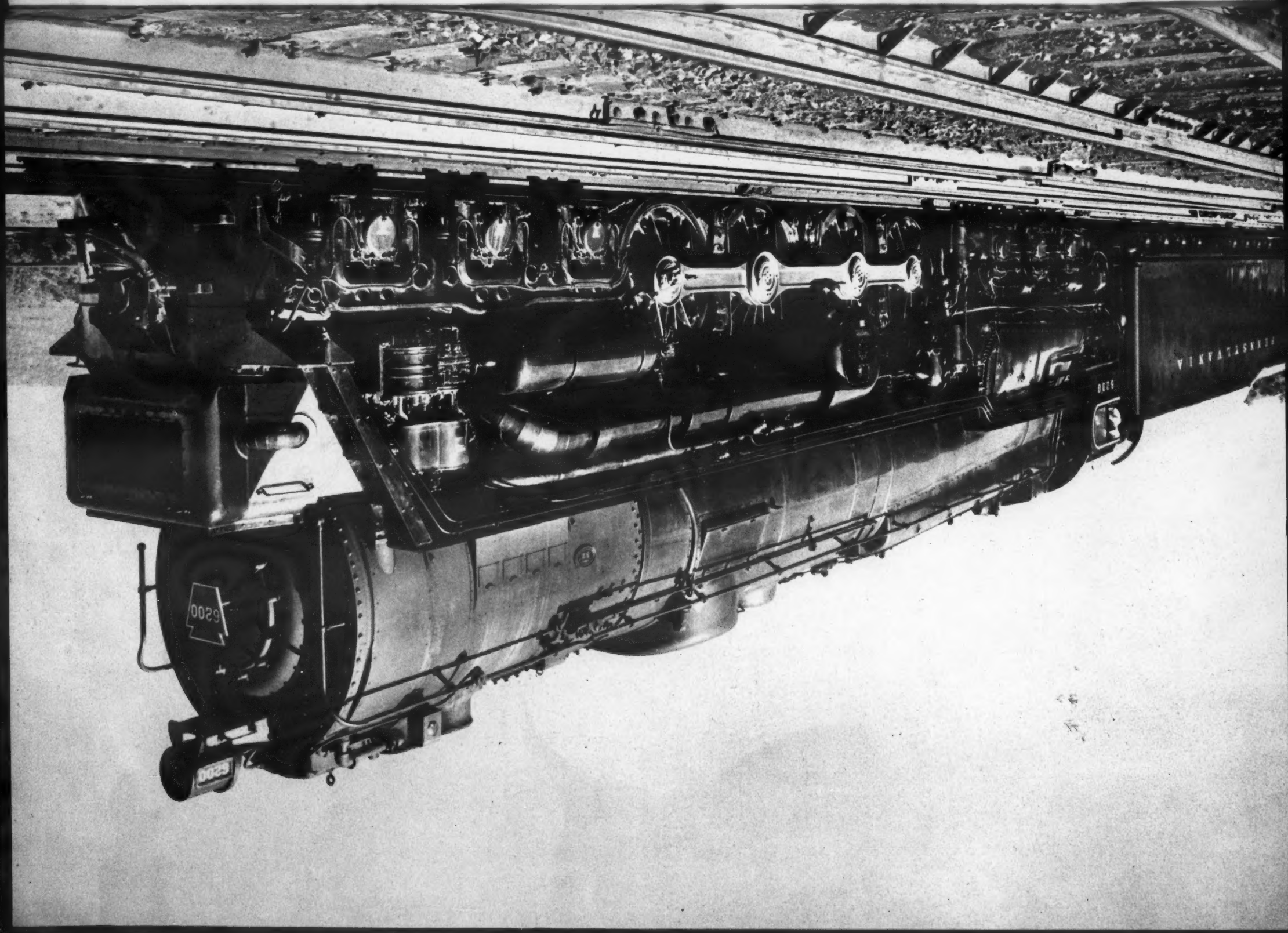
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S-2

By JOHN W. WEIL, 10-47

AS someone once said, it takes the choo-choo out of railroads. Far more important, the S-2 geared turbine locomotive promises to be one of steam's answers to the threat of the Diesel engine.

The idea for a turbine-driven engine grew out of Pennsylvania Railroad's environment. The Pennsylvania prefers to use coal-burning steam engines for several reasons. Its trackage lies in the heart of the coal mining district and is the principal transportation artery for the entire coal industry in that area. By using coal-burning locomotives, the Pennsylvania saves considerable money, since it is always close to its source of fuel, aside from the fact that it helps support the operation of the mines — and, consequently, insure continued shipments — by buying a part of the produce. In other words, the Pennsy carries, buys, and burns the coal which is so abundant in that part of the United States through which its tracks run.

For this reason the Pennsylvania has pioneered in the development of more efficient steam locomotives. On some parts of its line, the Pennsy uses electric engines to a great extent and with excellent success, but on the main line from Harrisburg to the West steam power is used for both passenger and freight trains.

Some of the Pennsylvania's experiments with new steam locomotive types were notable successes. At the New York World's Fair in 1939 Pennsylvania exhibited the world's largest steam engine and pronounced it the forerunner of a new type of locomotive. This S-1, as it is called, was over one hundred and forty feet in length, coupler to coupler, and was too long to be of much use in the East where sharp curves limit the size of an engine. Soon, however, the S-1 was supplanted by the T-1, a rigid-frame, streamlined steam engine which will soon become standard equipment on the Pennsylvania main line. Its wheels were arranged in sets, a four-wheeled leading truck, two pairs of driving wheels driven by two cylinders, a second set of four driving wheels and cylinders, and, finally, a four-wheeled trailing truck. It would be classified as a 4-4-4-4. The S-1 is a 6-4-4-6.

Almost simultaneously Pennsylvania announced a rigid-frame steam freight engine of almost unbelievable power for use in hauling wartime loads. This Q-2 engine, a 4-4-6-4, also was ordered in quantity for standard service. With these two types of engines, the Pennsy was well equipped to cope with any transportation problems which might arise.

Designers, working under the auspices of several railroads, equipment manufacturers, and coal producers, had other ideas that needed trying out. They drew up tentative plans for a turbo-electric steam engine, taking up where the Union Pacific Railroad left off when its experimental engine had failed to be successful.

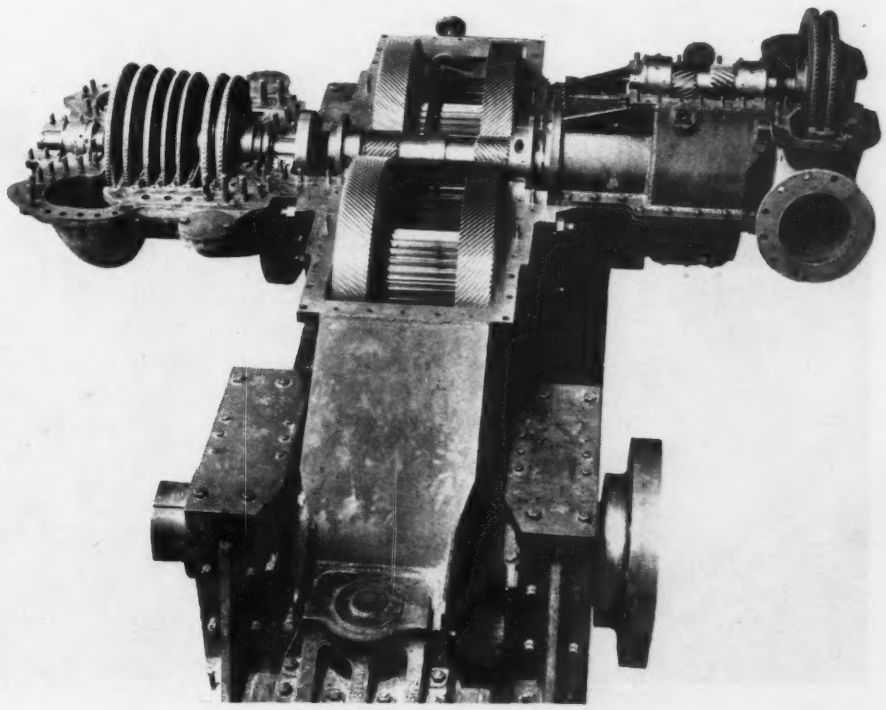
But all that was still far in the future. Something far more important and promising was nearing completion in the Baldwin erecting shops. It was the S-2, first direct drive, steam turbine locomotive ever to run in the United States.

Other railroads have tried various elaborate types of turbines. The Union Pacific built an engine that utilized steam power to generate electricity to drive the wheels, but it proved unsuccessful. Pennsylvania's new development is simplicity itself. Steam drives a turbine which, through gears, drives the wheels.

The S-2 looks surprisingly like most other steam engines, except that the usual drive rods are absent. Instead there is only one large connecting rod on each side. On further inspection, two medium-sized housings can be seen, one on each side of the locomotive, with several large pipes connected to them. These housings contain the turbines.

Superheated steam at three hundred and ten pounds pressure per square inch is piped to the forward-motion turbine housing on the right side of the locomotive.

Forward turbine, reverse turbine and transmission with housing removed
Courtesy Baldwin Locomotives



There the steam is fed through dozens of jets and enters the turbine itself at a speed of two thousand miles per hour. More than a thousand chromium steel blades, varying from less than one inch to about three inches in length, convert the steam's kinetic energy into rotational kinetic energy. The steam passes through one Curtis stage, consisting of two turbine rows with flow-correcting vanes mounted between them, and then through five Rateau stages, each being a single row turbine with its own jets and blades. By the time the steam leaves the turbine through the large exhaust pipes, which are visible on the exterior of the locomotive, all but fifteen pounds of pressure and a little heat have been extracted. Even this small amount of power is put to good use creating a smooth, continuous draft in the fire box and boiler tubes. The remaining steam and smoke is finally driven out of the smokestacks with a steady blowing sound — instead of the usual puffing.

The turbine, which has absorbed the energy taken from the steam, carries the power to the transmission and thence to the wheels. When running at its maximum operating speed of nine thousand revolutions per minute, the forward turbine delivers about six thousand nine hundred horsepower to the gear shaft. When the power is finally delivered to the wheels through the giant drive gears located on the axle of the two center pairs of driving wheels, it is sufficient to create about sixty five thousand pounds of starting tractive effort. The power is transmitted to the other two pairs of driving wheels through the roller-bearing connecting rods affixed eccentrically to the outside of the main driving wheels.

The transmission gears between the main driving wheels and the forward turbine are kept well bathed in lubricating oil by centrifugal pumps run by two small auxiliary turbines. The gear meshing is so efficient that ninety-seven per cent of the power delivered by the turbine reaches the wheels.

A second, smaller turbine is installed on the other side of the locomotive. This one, rated at fifteen hundred horsepower at eight thousand three hundred revolutions per minute, is used to drive the engine in reverse. When the main turbine is being used, the reverse turbine is disengaged by means of a clutch. When the engine is running backward, the main turbine rotates backwards in its housing since it can never be disconnected. The reverse turbine consists simply of a single Curtis stage with steam jets mounted in a semicircle around its circumference.

A steam turbine locomotive has many advantages. First and foremost it provides a more even tractive effort because of the elimination of the reciprocating parts found in other kinds of engines. At high speeds the steam turbine is considerably more efficient than other types of engines. Also, because of the elimination of all driving rods and the like, the wheels can be perfectly balanced and thus can be operated at higher

(*Continued on page 18*)

Another Pennsy success — one of the new T-1 locomotives

Courtesy Pennsylvania Railroad

APPLICATIONS OF BESSEL FUNCTIONS TO ELECTRICAL ENGINEERING

By ISAAY STEMPNITZKY, 6-45

ALTHOUGH there are publications, books as well as magazine articles, which treat the subject of Bessel functions from the engineering point of view more or less extensively, there is no treatment, as far as the author is aware, embodying an extensive survey of the uses of Bessel functions in electrical engineering. The present article sketches a few of the applications of Bessel functions to electrical problems.

In problems which deal with fluxes in cylindrical symmetries, very often we find, in the process of solution of a differential equation describing a phenomenon, a differential equation of the form

$$z^2\frac{d^2y}{dz^2}+z\frac{dy}{dz}+(z^2-\mu^2)y=0, \qquad (1)$$

where μ is a constant. This differential equation is called *Bessel differential equation of order* μ. To solve the above equation we assume a solution in the form of a power series, and it turns out that the expression

$$J_\mu(z)=\sum_{r=0}^{r=\infty}(-1)^r\frac{\left(\frac{z}{2}\right)^{\mu+2r}}{r!\,\Gamma(\mu+r+1)} \qquad (2)$$

satisfies the differential equation. The function $J_\mu(z)$ is called *Bessel function of order* μ *and argument* z *of the first kind.* Eq. 2 holds when μ is a positive number; negative orders being given by the relation

$$J_{-\bar{\mu}}(z)=(-1)^{\bar{\mu}}J_{\bar{\mu}}(z), \qquad (3)$$

where $\bar{\mu}$ is an integer.

The solution of Eq. 1 must have two arbitrary constants, that is, the form of the solution must be

$$y=AZ_1(z)+BZ_2(z), \qquad (4)$$

where A and B are constants and $Z_1(z)$ and $Z_2(z)$ are some suitably chosen functions of z. In the Theory of Wronskians we learn that these functions of z cannot be chosen arbitrarily, even though each one, by itself, satisfies Eq. 1. For example, if these two functions are connected by an equation of the type of Eq. 3, only one of these two functions could be used as part of the solution of the differential equation. Among the several kinds of Bessel functions which have been studied we may mention those of Weber, Hankel, Shclafli, Heine, and Neumann; all these are called *Bessel functions of the second kind.* In addition to these, there exist the *modified Bessel functions of the second kind, Bessel functions of the third kind,* and *Bessel functions of imaginary argument.*

We have seen that the mathematics of the problem imposes certain restrictions on the functions $Z_1(z)$ and $Z_2(z)$. In addition to these, the physics involved imposes further restrictions on these functions. For example, Weber's function, denoted by $Y_\mu(z)$, approaches infinity as z approaches infinity; this behavior may be physically impossible in a specific problem. Again, the modified Bessel function of the second kind, denoted by $K_\mu(z)$, approaches zero exponentially as z approaches infinity. Furthermore, some solutions of physical problems make use of two such functions which have "opposite" behavior; this case is illustrated by the equation of motion of the air in a loudspeaker where reflections from the mouth must be considered. In general, then, the types of functions chosen depend, first on the mathematics of the particular differential equation, and second on the physical behavior of the phenomenon at hand. With this very brief note we sketch the "theoretical" part of the paper.

One aspect of transmission-line theory where Bessel functions appear is in the general problem of distortion of currents. It is a familiar phenomenon that when an alternating current flows through a loop of wire which is situated in the vicinity of a second loop, the first loop will induce an e.m.f. in the second. A cable may be considered to be composed of an infinite number of very small elementary cylinders which form an infinite number of such loops. It is obvious, therefore, that the outside loops, when carrying alternating current, will induce a voltage on the inner loops. The final effect is that the inner cylindrical elements carry two "kinds" of currents: one due to the difference in potential between the two ends, and one due to induction. It is clear also that because of this behavior, the current at the skin of the wire will be greater than at the core. This phenomenon is called skin effect; it is based on Ampere's circuital rule, and on Faraday's induction law. By the use of these two principles it is possible to derive a differential equation giving the behavior of the current in a cylindrical cable. This differential equation is

$$r\frac{d^2i}{dr^2}+\frac{di_r}{dr}-jrk^2i_r=0, \qquad (5)$$

where r is the distance from the axis of the conductor (radius a) to the point in question, i_r is the current (assumed sinusoidal) at that point, and k^2 is a constant which depends on the material of the cable and on the frequency of the current. If the total current in the wire is I, then the solution for i_r in Eq. 5 is given by

$$i_r=j^{3/2}\frac{kI}{2\pi a}\,\frac{J_0(krj^{3/2})}{J_1(kaj^{3/2})}. \qquad (6)$$

From the above outline it is clear that on account of skin effect the resistance of conductors to alternating current will not be the same as the resistance to direct current. For frequencies of 50 cycles per second or less the increase in effective resistance is inappreciable for solid copper conductors up to about 0.5 inches in diameter. However, the increase in effective resistance is about eight per cent for one-inch copper conductors.

Proximity effect is another interesting phenomenon encountered in transmission line theory. In this case the distortion of the current in a conductor is considered

(*Continued on page 20*)

AMATEUR ROCKET RESEARCH AT M. I. T.

By ROBERT KRAICHNAN, 2-47

THE spectacular rôle which they have played in the European war have brought rockets and jet devices prominently and permanently before the eyes of the public. The popular conception of the rocket as a fit subject for the Sunday supplements has changed to the realization that liquid fuel rockets are a potent weapon in all-out warfare. A few years ago it would have seemed unbelievable to most people that a rocket could be constructed which would travel several hundred miles at a speed of over a mile per second and then drop a ton of high-explosive on its target. Today, however, the German V-2 rocket is a common topic of discussion. And, in fact, there is evidence that the Germans were on the point of developing rockets capable of crossing the Atlantic when the end of the war interrupted them.

Although the liquid fuel rocket saw its first major use as a war weapon, it should not be thought that it was first conceived for this purpose or that the development of such rockets was the exclusive work of military research. Actually, the first attempts at the construction of workable liquid-fuel rockets was the work of amateur enthusiasts and organizations who had as their ultimate object the construction of a rocket which could cross interplanetary space.

These organizations sprang up in Germany, England, and the United States after the close of the first World War. They did important pioneering work of both a theoretical and experimental nature, and by the time the present war opened, several rockets had been constructed which could be described as moderately successful. In addition to constructing the rockets themselves, these experimenters developed various devices for the control of rockets in flight, some of which have proved to be of military importance.

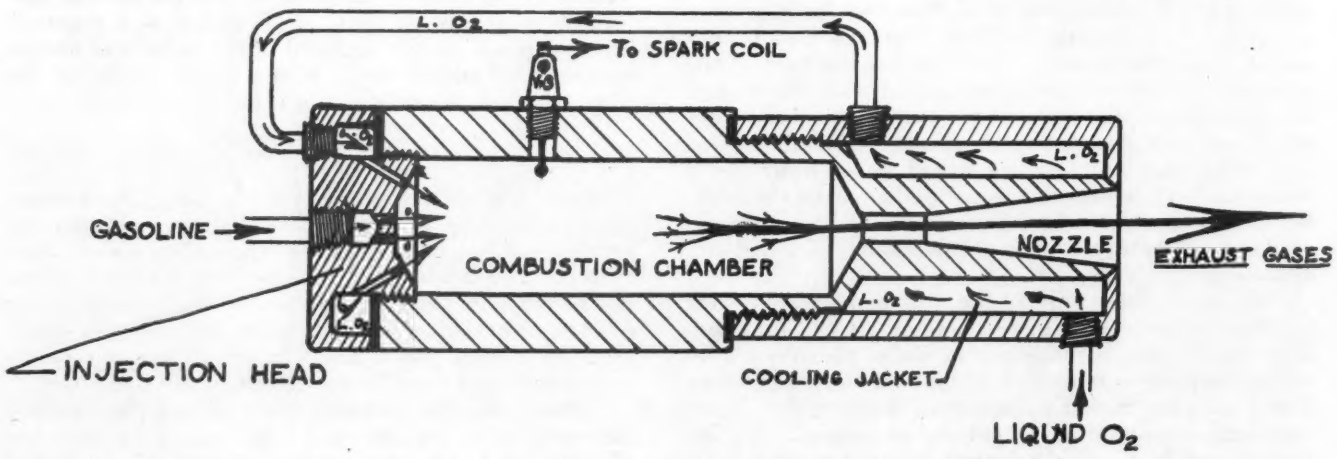
The most prominent of the early amateur rocket organizations was the German Rocket Society. This society was composed of a group of engineers and professional men. In the years since its founding, some twenty-five years ago, the organization constructed many rocket models, some of which were markedly successful. Their most successful motor was capable of running continuously for twenty minutes while yielding a thrust of over one hundred pounds.

When the Nazis seized control of the German government, they quickly dissolved the German Rocket Society. Some of the members, including the well-known author Willy Ley, fled to other countries. Others continued their work for the Nazis. Among this latter group was Hermann Oberth, the genius who is credited by many authorities to be the designer of the V-2.

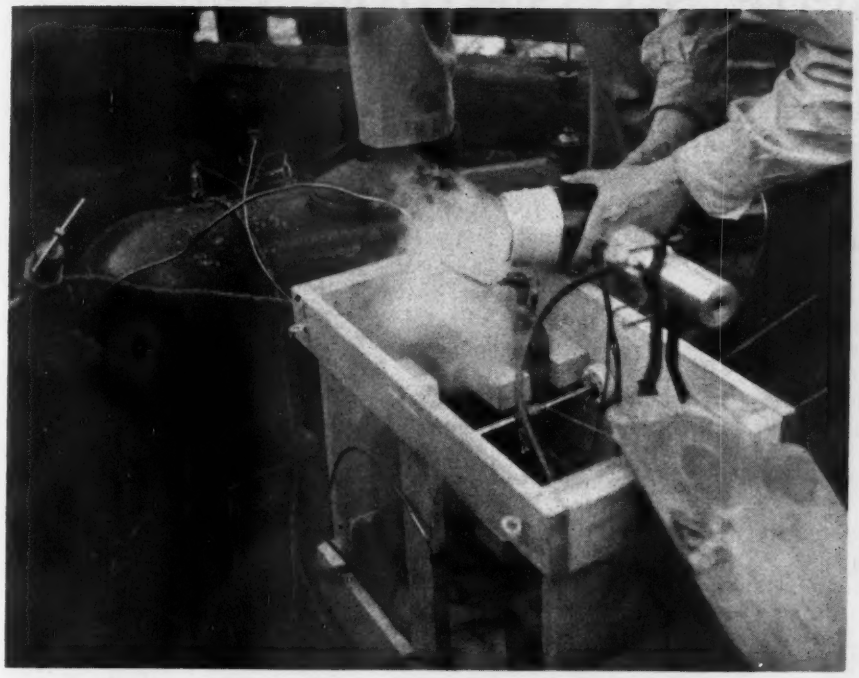
In the United States the most prominent amateur group was the American Rocket Society, with headquarters in New York. Their program was similar to that of the German organization. This society performed a very useful function by publishing a monthly pamphlet, *Astronautics*, which contained discussions of current amateur rocket work. In addition to this organization, a great deal of important work was done by Dr. R. H. Goddard, who conducted an extensive series of experiments in the New Mexican desert. Dr. Goddard holds a great number of patents of rockets and at one time constructed a projectile that ascended to a height of over one thousand feet.

The M.I.T. Rocket Research Society was born in 1940 when a group of rocket enthusiasts at Tech began to get together to discuss rockets and plan experimentation. In the past five years the Society has duplicated much of the experimental work of the older organizations and has, in addition, worked on many theoretical problems relating to rocket flight. Since the beginning of the present war, which drew many rocket experimenters into government laboratories, the M.I.T. Rocket Society has been the only organization in this country conducting an active experimental program.

In 1941 the Society was formally organized as the Massachusetts Institute of Technology Rocket Research Society. Its purpose was "to facilitate the advancement and dissemination of knowledge of rocket research." Soon after the Rocket Society's formation, a circular letter was sent to other organizations and



Typical liquid-cooled rocket motor. Aluminum construction throughout, designed to operate at 300 pounds per square inch



Pouring liquid oxygen into the pressure tank. The motor appears on the far right. Large tank on the left contains compressed nitrogen

individuals throughout the country announcing the formation and aims of the Society. Among the correspondents of the Society were the American Rocket Society, the Galcit Rocket Research Society (C.I.T.), and Dr. R. H. Goddard.

The original program of the Society revolved about the design and testing of rocket motors employing liquid fuels such as gasoline and liquid oxygen. It soon became evident, however, that an effective research program would involve investigation of many related fields. Accordingly, provision was made for the creation of three committees: the Technical Committee, the Experimental Committee, and the Publications Committee. A detailed program was then worked out. As of March 1, 1941, the program included investigation of such topics as design and construction of test apparatus; comparative study of fuels and oxidants; behavior of liquid oxygen; ballistics of rocket flight; methods of ignition; gas flow in rocket combustion chambers; control mechanisms; and the behavior of engineering materials at extreme temperatures.

In addition to this research program, the Society held public meetings at which the subject of rocketry was discussed and various speakers were heard. At the initial meeting the Society was addressed by Prof. F. W. Sears, of the Physics Department, and Dr. G. E. Pendray, nationally known authority on rockets and an officer of the American Rocket Society.

The primary object of the research program launched by the Society was to produce a light, workable rocket motor that would develop high thrust from liquid fuels and would be sufficiently durable to permit long flights. This was, of course, the principal problem faced by all the experimenters and amateur organizations.

Over a year was required before the Rocket Society was able to evolve a workable plan and design suitable test apparatus. Additional time was required to obtain materials and build the equipment. The first field test was finally held during the winter of 1943–44. The rocket motor used in this test consisted of a tubular steel chamber lined with a ceramic inner layer which was shaped according to thermodynamic considerations. The fuels used were carbon disulfide and compressed nitrous oxide. The carbon disulfide was forced through the fuel line into the combustion chamber by the backing pressure of a tank of compressed carbon dioxide. After mixing in the combustion chamber, the gases were ignited by means of a spark-coil and model airplane spark plug.

Provision was taken in this initial test to take various experimental data throughout. A spring-actuated gauge measured the thrust given by the motor. Other instruments measured pressures, and a standard of reference was provided by a clock mounted upon the test apparatus.

This first test exposed many defects in the experimental set-up. The principal fault was that the rate of injection of gases into the combustion chamber was not sufficient to prevent striking back, and, as a result, the fuel lines exploded.

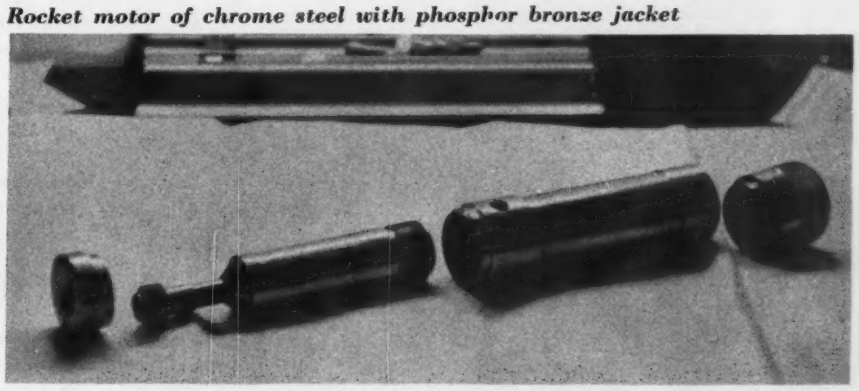
These defects were studied and corresponding refinements were made in the test apparatus. Several other tests were then held with this and other motors, using nitrous oxide and either carbon disulfide or ether for fuel. At one of these tests, a maximum of eight pounds of thrust was obtained from a motor with a throat diameter of one-eighth inch. Assuming a chamber pressure of several hundred pounds per square inch, this figure is of the order of magnitude that is to be expected, as can be crudely verified by multiplying the area of the throat by the chamber pressure.

In the early summer of 1944 it was decided that an attempt should be made to use fuel combinations with a higher heat of combustion. In particular it was desired to conduct tests with liquid oxygen and gasoline.

The first test with these fuels was held late in August. The motor used was constructed entirely of aluminum, in order to conserve weight. It consisted of injection head, spark plug, combustion chamber, and expansion nozzle. This test was a marked success. Very violent combustion was obtained within the combustion chamber and a thrust of fifteen pounds was developed. The diameter of the throat of the motor

(*Continued on page 26*)

Rocket motor of chrome steel with phosphor bronze jacket



THE AIRSHIP'S CHALLENGE

By THOMAS G. SWALLOW, 10-47

WHEN the *Hindenburg* burned at Lakehurst, on May 6, 1937, many laymen thought that the day of the airship was over. However, airship circles recommenced planning to make all airships safer than airplanes by means of the inert gas, helium.

An airship flies because it displaces more than its own weight of air by means of a great volume of light gas. Because of this feature, airships, like boats, are measured in terms of their displacement. The lift that an airship derives from its buoyancy is known as static lift. In an airship of 10,000,000 cubic feet displacement, the static lift would be about 350 tons.

Usually the light gas is hydrogen or helium. Hydrogen is the lightest gas, and a litre will displace a weight of air equal to its own weight plus 1.024 grams. Helium, the second lightest element, displaces its own weight of air plus 1.115 grams per litre. Helium is therefore 92.64 per cent as buoyant as hydrogen. In cost, helium is between three and five dollars per 1000 cubic feet, while hydrogen is between two and eight dollars per 1000 cubic feet. A large demand for either would force the price downward. Hence, unless other considerations are taken into account, there is little difference between the gases. The one point where an appreciable difference in qualities appears is on the question of inflammability, an all-important one to airships. Helium is an inert gas. Hydrogen is one of the most highly inflammable substances known, and hence is no longer used.

When an airship is in motion, lift is obtained from the airfoil action of the hull, as well as from the buoyancy of the gas. In a dirigible of 10,000,000 cubic feet, this dynamic lift would be about 30 tons, or 10 per cent of the static lift. With modern airfoils, it is expected that this figure will be considerably increased.

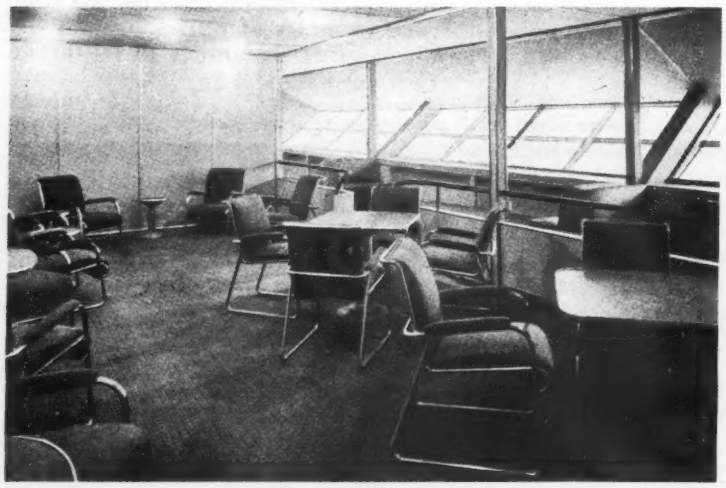
The first airship was flown September 14, 1852, at Paris by Giffard, a Frenchman. From then until 1900 limp airships were tried with many types of power plants, steam engines, electric motors, and gasoline engines. In 1901, the French non-rigids had a brief triumph. On October 19 of that year, Santos-Dumont, the famous Brazilian aeronaut, flew around the Eiffel Tower to win the Deutsche de la Meurthe Prize — one hundred thousand francs.

A year earlier, in Friedrichshafen, Wurttemburg, on the Bodensee Graf Felix von Zeppelin flew the first successful rigid airship. Prior to this time all airships had been of the inflated gas-bag type, which held form due to internal gas pressure. Graf von Zeppelin's ship had a rigid framework inside which the gas cells were mounted. Zeppelin's *LZ-1*, a 425-foot ship powered by two 16-horsepower engines, flew for 18 minutes. In October 1900, the Zeppelin flew twice more. On the seventeenth it made a flight of 80 minutes, and on the twentieth, another of 23 minutes. In 1909 the Zeppelin *LZ-5* set an endurance record of 38 hours.

In 1910, the first passenger dirigible, the *LZ-7*, the *Deutschland*, was built for Delag, the Deutsche Luftschiffahrts-Aktiengesellschaft, the German operating company, a subsidiary of the Zeppelinwerke. From then until 1914, Delag operated passenger service between the principal German cities. In four years it used five ships, *Deutschland*, *Schwaben*, *Hansa*, *Victoria-Luize*, and *Sachsen*. These five dirigibles made 1600 flights covering 100,000 miles in four years. They carried 37,000 passengers. Delag lost the first two airships; one crashed, and the other burned, both without passenger fatalities, but at the cost of one of the crew.

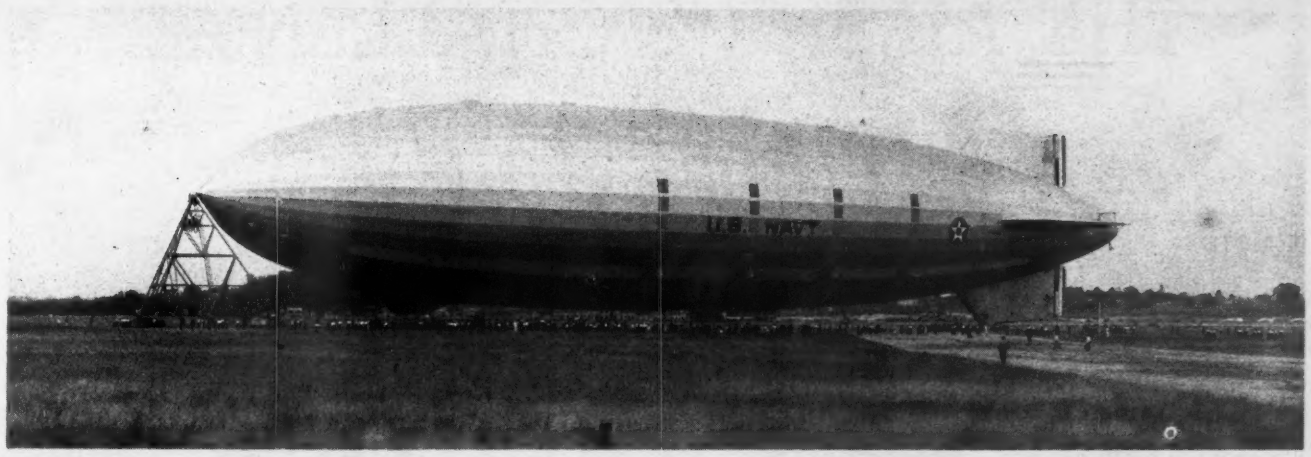
The advent of the first World War put a stop to commercial dirigible development. It did give stimulus to the development of military airships. Germany constructed mostly rigid airships, and built 88 Zeppelins, and some Schutte-Lanz type ships. The Allies concentrated on non-rigids. England used small non-rigids extensively and successfully in anti-submarine work. (It was from the English "Class 'B' Limp" that the modern word "Blimp" was derived.) France and Italy experimented to a lesser degree with non-rigids. The United States built and maintained eight non-rigids. During the war, the British built three rigid airships, one of which, the *R-34*, made the first East-West flight across the Atlantic, when, in July 1919, it flew the 3600 miles from Scotland to Mineola, New York, in 108 hours. Shoftly after the Armistice, the United States laid down the *ZR-1*, the *Shenandoah*, designed from a German airship which landed intact in England.

The starboard promenade deck of the Hindenburg. *Note the windows which were kept open, with no draft and a minimum of noise.*



By the terms of the Treaty of Versailles, the German government was compelled to hand over the entire dirigible fleet, and was forbidden to construct any new ships. The Zeppelinwerke was to be demolished, and all the airship sheds but two, one at Berlin-Staaken and one at Rhein-Main, were to be dismantled. The German airship crews, however, scuttled their ships and as a result, the German government was compelled to build a larger Zeppelin for the United States. The *LZ-126*, the *Los Angeles*, was begun in 1923. Its construction kept the Zeppelinwerke going, and removed it from the Allied ban.

The *Los Angeles* was completed in the summer of 1924, and started its trans-Atlantic



The U.S.S. Akron *at Akron, Ohio, 1931* — *Goodyear Aircraft Corporation*

flight in October of that year. The 5,000 mile flight was completed in 81 hours.

Shortly after the arrival of the *Los Angeles*, Goodyear Tire and Rubber Company of Akron, Ohio, built its first commercial blimp, the 51,000 cubic foot *Pilgrim*. In 1929, Goodyear began building the blimp fleet which has been the mainstay of American airships.

In 1928 the Zeppelinwerke completed the *LZ-127*, the *Graf Zeppelin*. The *LZ-127* was the first postwar commercial Zeppelin, but was designed not as a passenger ship, but for training purposes. The *Graf* operated experimentally across the North Atlantic. It flew around the world with but three stops. From 1930 until it was decommissioned after the *Hindenburg* fire in 1937, the *Graf* maintained commercial service between Friedrichshafen and Rio de Janeiro. When it arrived in Rio on one trip, the landing crew was insufficient to land the ship and march it into the hangar. Undaunted, the captain flew the Zeppelin into the hangar under its own power, and landed it inside.

While the *Graf* was making a name for herself, the United States Navy contracted for two dirigibles with the Goodyear Company. The first was started in 1928, and completed in 1931 as the *ZR-4*, the *Akron*. The second was completed in 1933 as the *ZR-5*, the *Macon*. The ships were sister ships of 6,500,000 cubic feet. Each was equipped with a trapeze to launch and recapture airplanes, and each ship had a normal complement of five pursuit planes to use for scouting and for protecting the mother ship. The *Akron* crashed into the Atlantic in 1933 due to a faulty altimeter. Two years later the *Macon* sank in the Pacific because of an unrepaired structural failure.

In 1936 the Zeppelinwerke completed the first of two sister ships, the *LZ-129*, the *Hindenburg*, and laid down the second, the *LZ-130*, the *Graf Zeppelin II*. The *Hindenburg* originally entered the South American service, but in May 1936 was transferred to the North American run. During 1936 the *Hindenburg* made ten 8,000-mile round trips from Rhein-Main (near Frankfurt-am-Main) to Lakehurst. In the following year she was scheduled to make 18 trips. On the first trip the hydrogen cells of the ship caught fire, and the airship was destroyed, taking the lives of 13 passengers, the first Zeppelin passenger fatalities in 36 years of operation. Twenty-two of the crew were killed.

After the *Hindenburg* holocaust the *Graf Zeppelin* was decommissioned, pending the arrival of helium from the United States. The United States, however, refused to export helium, and neither the *Graf Zeppelin* nor the *Graf Zeppelin II* flew again until the beginning of the Second War. Reasonably well authenticated reports indicate that both ships were used as cargo carriers between Germany and Russia to bring ore from the Ural Mountains. The British were sufficiently disturbed by these reports to spend valuable planes bombing Friedrichshafen during the spring of 1940.

Since the war little is known of the state of foreign airships, but it is presumed that Russia has at least two which had been designed for the Moscow-Leningrad run. In the United States, blimps have been extensively and very successfully used in submarine warfare and for convoy work.

The general structure of a dirigible consists of polygonal transverse "rings" which taper toward both ends of the ship. Joining these formers are longitudinal stringers connecting the vertices of the polygons. The polygons are laced with wire and ramie-cord to form flexible bulkheads which contain the gas cells. The stringers are laced together with wire to give the outside of the hull its shape. Over the hull a cover is fitted.

At or below the axial line a longitudinal keel is laid which gives strength to the ship, and which forms a passageway for the crew. At the stern of the ship the tail empennages are fixed. These commonly consist of two horizontal stabilizers with elevators attached, and two vertical stabilizers with rudders attached. At least one ship has been built with as many as six stabilizers.

The motors which power the ship are mounted either in the ship or below it. The control station is always in the lead gondola. Passengers may be carried either in the gondolas or in the hull of the ship.

A Zeppelin airship is distinguished by the fact that it has a single keel in the lower portion of the hull. This forms the longitudinal passage. Along it are located the crew's quarters, as well as fuel and ballast tanks, store rooms, and cargo space. In the *Hindenburg* the keel was supplemented by an axial corridor which ran through a cloth sleeve down the center of each gas cell, from bow to stern. In the *Graf Zeppelin* the main keel was located higher than in the other Zeppelins; it ran just below the axial longitude.

The Goodyear ships, the *Akron* and the *Macon*, each had three keels. One was located at the top of the hull, and one was located on either side of the ship, 70° below the horizontal. The extra keels gave the ships extra longitudinal and torsional strength.

The materials out of which the keels, stringers, and frames are made were originally aluminum, in the Zeppelins, and wood in the Schutte-Lanz type. The British *R-101*, around 1930, used steel for the frames.

(*Continued on page 22*)

Landing a two-engined Navy K-Class blimp
Aero Digest, New York

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ONE MORE VOLUME . . .

At the close of each scholastic year here at Tech, our magazine loses a portion of its old staff and gains a new one. The last pages are closed upon one more volume; and we, the new staff, must open the next, striving to carry on as well as we can the work of those before us. Every college magazine faces this problem, and it is one of the chief reasons why it is so difficult for them to develop the consistent editorial policies and accomplished style of writing which distinguish the publications of the commercial press and business world. However, with each change of staff, we have the advantage of a somewhat fresher outlook and the opportunity to improve our work.

From our staff of some two dozen men last June we lost fully one-third through graduation, the "Selective" Service, and (we grieve to say it!) *other* reasons. Among this group were half of our Board Members. This is not an uncommon situation among college publications at the present time, since many of them are being run by smaller staffs than before the war. Particularly manifest is the scarcity of upperclassmen, resulting in a staff that is not only smaller than usual but also less experienced. When the news of our recent staff appointments was released, the most frequent comment made by the students was "My God, they *must* be desperate!" With some slight modifications for purposes of publication, that about expresses our opinion, too . . .

However, despite the somewhat pessimistic tone of the preceding paragraphs, the *T.E.N.* looks forward to brighter prospects than it has had in years. The developments in the various fields of Science and their applications in Engineering, after the acceleration of almost four years of war, have received an impetus that will carry well into the future. Already, with the new volume hardly under way, material for many articles on these topical subjects is at hand together with the men who will write it up. Also in line is the continuance of our series *This is M.I.T.*, with articles covering those of the departments not hitherto represented.

The present staff, though small, is surprisingly industrious (apparently no one is flunking physics yet) and contains a talented group of writers. All in all, what appeared to be a lame duck at the end of last term — after the depredations of the draft, the final reprieve of graduation, and the tactful (?) silence that cloaks the disappearance of those who failed one too many quizes and had to fold their slide rules and silently steal away — has become imbued with unprecedented energy and will soon fly as high as ever before.

As each successive staff begins its work, it has the option of deciding whether or not to put out an August-September number since this Summer Issue, as it is called, is not necessary to the new volume. Whether or not this issue can be successfully produced is determined by the state of organization of the staff and by the amount of material on hand. That we are in a position to put out this issue is a tribute to the fine work done by last term's staff. John Howkins, General Manager of Volume XXVI, and Dick Marsten, our Editor-in-Chief, did a swell job and especially deserve both our thanks and our congratulations.

As for our editorial policies (few and far between as they are!), it might be wise to take this opportunity to indicate their general trend. Some criticism has arisen in the past to the effect that the editorial page of an engineering magazine is not the place to fight the political battles of the day. This argument is lent rather pointed emphasis by the fact that the editorials are usually written some time before the magazine actually makes its appearance, which has seriously out-dated more than one such editorial in the past.

It is true that certain international problems and the complications which arise from them have no place here, particularly those in which our own nation is not directly involved, nor will their discussion here appear. However, there are few major problems before our country which will not eventually affect even the semi-isolated engineers; therefore, it might prove to be a little difficult to determine just where the line ought to be drawn. The engineer, despite his profession, should be interested in more of his surroundings than the location of the nearest calculating machine or redhead. Our opinion is that a great many of our national problems are of importance to the engineer and may justifiably be used as editorial material.

And now, with its desks cleared for action and the staff at their typewriters, the *T.E.N.* begins one more volume to record the march of Technology.

S. L. S.

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BELL TELEPHONE SYSTEM

"Service to the Nation in Peace and War"

S-2

(*Continued from page 8*)

speeds. This helps minimize track pounding and allows the size of the wheel to be considerably reduced even on high speed passenger engines. Wheels have been up to eighty-four inches in diameter — on the S-1 — but the drivers on the S-2 are only sixty-eight inches high. Because of this the engine appears tall compared to the wheels, although it is no higher than the normal type of steam engine.

Another strong point of the turbine locomotive is the simplicity of its control system. Instead of having a throttle bar and separate reverse lever to work, the engineer simply uses a small handle looking much like an automobile gear shift to control the direction of travel and the speed. The control also resembles the shift on a car in its operation, as it has a neutral point where the lever may be pulled from side to side. To make the engine go forward the control handle is pulled to the right and moved forward. It is as simple as that. To increase the forward speed of the engine the handle is pushed further and further forward. To drive the engine in reverse, the control is pulled to the left in the neutral position and pulled back — the distance to the rear controlling the speed of the engine in reverse.

From the railroad's point of view, the S-2 has another important advantage. On the turbine locomotive the weight is set in the center of the engine and is more evenly distributed over the wheels. Most engines have their pistons and cylinders located far forward. This tends to make the front wheels carry more of the weight and consequently wears out both the track and the wheels more quickly. With even distribution of the weight in the S-2 and a lack of reciprocating parts, greater track economy at high speeds is attained as pounding is reduced to a minimum.

But the turbine also has its disadvantages. The initial cost of the S-2 was high, and the "bugs" have yet to be ironed out. However, when the engine goes into full service and if more of its kind are built, the cost is expected to drop to that of a comparable locomotive of more conventional operation. For repairs the entire turbine unit will be replaceable so that an engine will not be kept out of service while major repairs are being made. High steam consumption at low speeds is a problem. However, progress in research is being made, and these points will be taken care of.

The facts and figures on the other parts of the S-2 are conventional. Fully loaded, the locomotive and tender weigh over a million pounds, with about two hundred and sixty thousand pounds on the driving wheels. It is a total of one hundred and twenty-three feet long and sixteen feet high. It can carry thirty-seven and a half tons of fuel, enough to drive it about two hundred and twenty miles at speeds of at least a hundred miles per hour. The wheels are in a 6-8-6 arrangement, that is, a six-wheeled leading truck, eight drivers, and a six-wheeled trailing truck. The tender is of standard Pennsylvania sixteen wheel design. An automatic stoker is fitted to the fire box, and the cab contains all the standard gauges plus the new type control lever. The controls having to do with the turbine are operated pneumatically and have automatic safety devices built into them. All wheels have full air-brakes, both on the tender and on the engine.

For the last several months the S-2 has been used west of Harrisburg pulling a regular train once a day as an experiment. The train usually consisted of ten cars. Once, as a further trial, the Pennsy coupled the engine to twenty cars — two more than the longest train ever run regularly on the Pennsylvania system. The night turned out to be cold, and the rails were wet, but the test went through anyhow. The engineer started out and near the end of the run, according to his own words, had to slow down and coast the rest of the way to avoid coming in ahead of time.

Recently the S-2 was dismantled for inspection and cleaning and was put back into service near Chicago. Sometime this fall it will go into the Altoona test shops — the only existing testing lab for a full-sized engine — and will be given a thorough check-over. Only then may we hear of any definite developments as to the results of the tests and whether the Pennsy will order more of the same or similar types.

Inevitably man dreams of something new. With the S-2 nearing maturity, Pennsylvania engineers have gone back to designing and have come up with another new engine design. Designated solely as the "Triplex," this new goliath is still on the drawing boards, but some details are known.

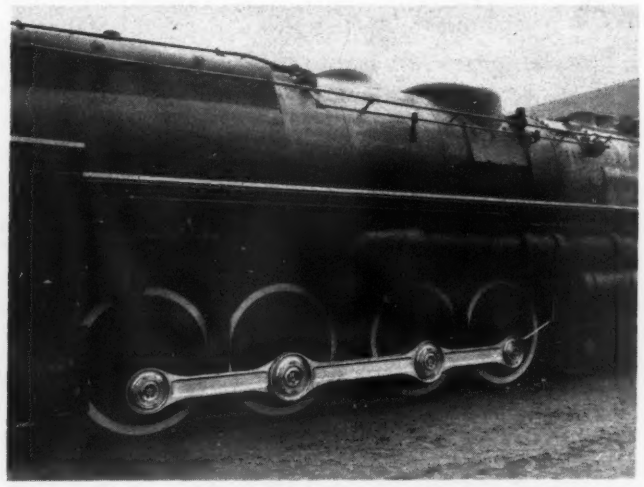
A noticeable thing about this new locomotive is the order in which the different units come. At the front end is the coal compartment, followed by the cab, the fire box, the boiler, and the smoke stack respectively. After that will come the tender which will carry only the water. This peculiar arrangement allows for better automatic feeding of the fire as the coal container is mounted on the same body as the fire box and no jointed feed systems are necessary.

The most unique feature of the whole engine is the way in which the main driving wheels are mounted. Under the main coal and boiler section are two swivelling trucks. Each truck consists of two pairs of guide wheels and four pairs of driving wheels. These drivers will be powered by steam turbines similar to the ones on the S-2. The two turbines — one for each set of trucks — will have a total of about nine thousand horsepower. Because of this unique method of having pivoting main drive wheels arranged in two units, the engine will fit around any curve in the track that a Pullman car will take. This is because the rigid length of the locomotive will bridge the inside of a curve instead of pivoting in one place and protruding on the outside of the curve at both ends.

Another interesting development is the system used for keeping a uniform weight on the sixteen driving wheels regardless of the amount of coal in the forward bins. As coal is used up, automatic pumps bring water up from the tender into special tanks in the base of the

(*Continued on page 20*)

Right-side view of the S-2, showing the forward turbine *Courtesy Baldwin Locomotives*



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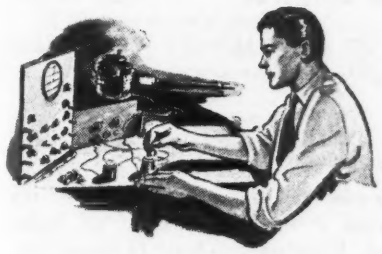

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The objectives of this unique search are threefold: to discover high school seniors of exceptional scientific aptitude – to focus their attention on the need for developing scientific knowledge and skill in research – and to make the American public aware of the importance of science in their daily lives.

HOW ENTRANTS ARE TESTED

Examination of entrants in Science Talent Searches is based largely upon rigorous science aptitude tests – to determine their research ability, reasoning powers and breadth of scientific knowledge. These tests are prepared by Dr. Harold E. Edgerton and Dr. Steuart H. Britt, prominent educators and psychologists.

HOW THE SEARCH IS CONDUCTED

Each year, high school seniors all over America compete for Westinghouse Science Scholarships, of a total value of $11,000, by taking these aptitude tests and submitting original science essays. Selection of the 40 finalists in the Annual Science Talent Search is based upon their records in aptitude tests, scholastic standing, recommendation of teachers, and science essays, in the order given.

WHAT IT HAS ACCOMPLISHED

To date, 160 brilliant youngsters–winners of Science Talent Searches – have been awarded $41,500 in Westinghouse Science Scholarships. In addition, 429 winners of Honorable Mentions in the *first two* Science Talent Searches have received scholarships, valued at $132,450, from other sources. Of perhaps greater importance, a continuing study of one of the early Searches has disclosed that more *than 75% of those who entered this competition have actually gone to college – against a national average of only 35% for high school students!*

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SEND FOR SCIENCE TALENT SEARCH LEAFLET

If you are the parent of a scientifically-gifted boy or girl who will be a high school senior this fall . . . or if you know of such talented youngsters . . . send for Science Talent Search Leaflet EC-85 which gives full information about these competitive awards. Write: Westinghouse Electric Corporation, Box 1017, Pittsburgh 30, Pa.

Tune in: JOHN CHARLES THOMAS—Sunday, 2:30 pm, EWT, NBC • TED MALONE—Monday through Friday, 11:45 am, EWT, Blue Network

S-2

(*Continued from page 18*)

front part of the engine. This shifting of the water will keep an even balance on all wheels. As the coal compartment is refilled, the water is pumped back into the tender.

The "Triplex" will probably be the largest engine that can be operated on American rail systems. It will cover well over a hundred and thirty-seven feet of track with a wheel base of a hundred and twenty-three feet.

The steam turbine, through such engines as the S-2 and the "Triplex," may well turn out to be the most important railroad development since the Westinghouse air-brake.

BESSEL FUNCTIONS

(*Continued from page 9*)

to be caused by elementary cylinders of current flowing *outside* of the conductor. Thus proximity effect and skin effect are only two aspects of the same general phenomenon of distortion of currents. This assertion was proved mathematically by Mannerback in 1922.

The use of Bessel functions in transmission-line theory instead of the more familiar hyperbolic functions simplifies problems considerably. Consider a transmission line where Z is the series impedance per unit length at a point, and Y is the shunt admittance per unit length at that point. Let the voltage at this point be E (with reference to a certain point) and the current through it I. Then, from Ohm's law,

$$dE=-IZdx \tag{7}$$

and

$$dI=EYdx. \tag{8}$$

Assume that

$$Z=zx^{\alpha} \tag{9}$$

and

$$Y=yx^{\beta}, \tag{10}$$

where α and β are constants. Assume also that

$$E=x^{p}u \tag{11}$$

and

$$w=x^{q}, \tag{12}$$

where $p=\frac{1+\alpha}{2}$ and $q=\frac{\alpha+\beta+2}{2}$. Solving Eqs. 7 and 8 simultaneously the result is

$$\frac{d^2u}{dw^2}+\frac{1}{w}\frac{du}{dw}-\left[k^2-\frac{v^2}{w^2}\right]u=0, \tag{13}$$

where $k^2=\frac{4yz}{(2+\alpha+\beta)^2}$ and $v^2=\left(\frac{1+\alpha}{2+\alpha+\beta}\right)^2$.

The solution of Eq. 13 is

$$u=AJ_{v}(kwj)+BJ_{-v}(kwj) \tag{14}$$

provided v is not an integer. This restriction is imposed on account of Eq. 3. Substituting the corresponding values in Eq. 14, and making use of Eq. 11, the final expression for the voltage is

$$E=x^{\frac{1+\alpha}{2}}\left[AJ_{v}\left(\frac{2j\sqrt{yz}}{2+\alpha+\beta}x^{\frac{\alpha+\beta+2}{2}}\right)+BJ_{-v}\left(\frac{2j\sqrt{yz}}{2+\alpha+\beta}x^{\frac{\alpha+\beta+2}{2}}\right)\right]. \tag{15}$$

By analogy, the expression for the current may be obtained by substituting in Eq. 15, β for α. If $\alpha=\beta=1$, the line is called *uniform*. If $\alpha=-\beta=-1$, the line is called *Heaviside-Bessel*. If $\alpha+\beta=2$, the Bessel functions lose their physical meaning and the whole equation for voltage must be derived anew. The result is not a Bessel differential equation.

As in the case of current distortion effects, Bessel functions occur in waveguides because of the particular symmetry of the system. Consider a homogeneous isotropic dielectric of permeability μ, dielectric constant ϵ, and conductivity zero. For this medium Maxwell's equations may be written as

$$\frac{\epsilon}{c}\frac{\partial \mathcal{E}}{\partial t}=\text{curl } H \tag{16}$$

and

$$-\frac{\mu}{c}\frac{\partial H}{\partial t}=\text{curl } \mathcal{E}, \tag{17}$$

where $\mathcal{E}$ and H are the electric and magnetic intensity vectors respectively and c is the velocity of light. Gaussian units are used. Eliminating $\mathcal{E}$ or H from Eqs. 16 and 17 we get the wave equation.

The curl of a vector R in general coördinates may be written as

$$\text{curl } R=\frac{u_1}{h_2h_3}\left[\frac{\partial(h_3R_3)}{\partial u_2}-\frac{\partial(h_2R_2)}{\partial u_3}\right]+\frac{u_2}{h_3h_1}\left[\frac{\partial(h_1R_1)}{\partial u_3}-\frac{\partial(h_3R_3)}{\partial u_1}\right]+\frac{u_3}{h_1h_3}\left[\frac{\partial(h_2R_2)}{\partial u_1}-\frac{\partial(h_1R_1)}{\partial u_2}\right]. \tag{18}$$

For cylindrical coördinates, which will be the case treated here, $u_1=r$, $u_2=\theta$, and $u_3=z$. Also, $h_1=1$, $h_2=r$, and $h_3=1$. Substituting the value of curl H and curl $\mathcal{E}$ in Eqs. 16 and 17, and by making use of Eq. 18, six equations are derived: three for the components of $\mathcal{E}$ in terms of derivatives of H and three for the components of H in terms of derivatives of $\mathcal{E}$. Assuming $H_3=0$ and $\mathcal{E}_3=0$ — this fixes the position of the axes — the result may be put into the form

$$H_1=\frac{jw\epsilon}{c}\frac{1}{h_2}\frac{\partial U}{\partial u_2} \tag{19}$$

and

$$H_2=-\frac{jw\epsilon}{c}\frac{1}{h_1}\frac{\partial U}{\partial u_1}. \tag{20}$$

The angular frequency of the quantities that vary sinusoidally with time is w. From Eqs. 19 and 20 and the corresponding expression for H_1 and H_2 in the group of six equations mentioned, it is possible to derive the following relation

$$\mathcal{E}_3=\frac{\partial^2U}{\partial u_3^2}+\frac{w^2}{v^2}U. \tag{21}$$

Substituting this equation in the corresponding equation of the group of six equations, we obtain the differential equation satisfied by the function U. In cylindrical coördinates this equation may be written as

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial U}{\partial r}\right)+\frac{1}{k^2}\frac{\partial^2U}{\partial\theta^2}+\frac{\partial^2U}{\partial z^2}+\frac{w^2}{v^2}U=0 \tag{22}$$

where $k^2-\left(\frac{w}{v}\right)^2$ is called the propagation constant; it will be denoted by γ. The solution of Eq. 22 is of the form

$$U=\begin{cases} J_n(kr)\cos \\ Y_n(kr)\sin \end{cases} n\theta\, e^{-\gamma z}. \tag{23}$$

Since Weber's function approaches infinity as r approaches zero, the final form of this equation may be written as

$$U = J_n(kr) \cos n\theta \, e^{-\gamma z}. \tag{24}$$

Since there is no Poynting vector component perpendicular to the conductor surface, U must vanish at the surface, and this gives the values of k to be used. From physical considerations one comes to the conclusion that the propagation constant must be imaginary, so that not all k's given by the relation

$$J_n(ka) = 0 \tag{25}$$

may be used.

We are now in a position to write the six components in question. For the waves which have $H_z = 0$, called $\mathcal{E}$ *waves* the components are given by

$$\begin{aligned}
\mathcal{E}_z &= k^2 J_n(kr) \cos n\theta \, e^{-jbz} \\
\mathcal{E}_r &= -jbk J'_n(kr) \cos n\theta \, e^{-jbz}, \\
\mathcal{E}_\theta &= \frac{jbn}{r} J_n(kr) \sin n\theta \, e^{-jbz}, \\
H_z &= 0, \\
H_r &= -\frac{jw\epsilon n}{rc} J_n(kr) \sin n\theta \, e^{-jbz}, \\
H_\theta &= -\frac{jw\epsilon k}{c} J'_n(kr) \cos n\theta \, e^{-jbz},
\end{aligned} \tag{26}$$

where $b^2 = -\gamma^2$.

Similarly, for the waves which have $\mathcal{E}_z = 0$, called H *waves*, the components are given by

$$\begin{aligned}
H_z &= k^2 J_n(kr) \cos n\theta \, e^{-jbz}, \\
H_r &= -jbk J'_n(kr) \cos n\theta \, e^{-jbz}, \\
H_\theta &= \frac{jbn}{r} J_n(kr) \sin n\theta \, e^{-jbz}, \\
\mathcal{E}_z &= 0, \\
\mathcal{E}_r &= \frac{jw\mu n}{rc} J_n(kr) \sin n\theta \, e^{-jbz}, \\
\mathcal{E}_\theta &= \frac{jw\mu k}{c} J'_n(kr) \cos n\theta \, e^{-jbz}.
\end{aligned} \tag{27}$$

The first wave has been designated as electric because there is a component of electric force in the direction of the Poynting vector. For a similar reason, the second wave is known as magnetic wave. This designation does not mean that either component exists alone.

Up to this point, Bessel functions have appeared as a result of solving a differential equation. In frequency modulation, however, Bessel functions appear in quite a unique way. A frequency modulated signal has the form

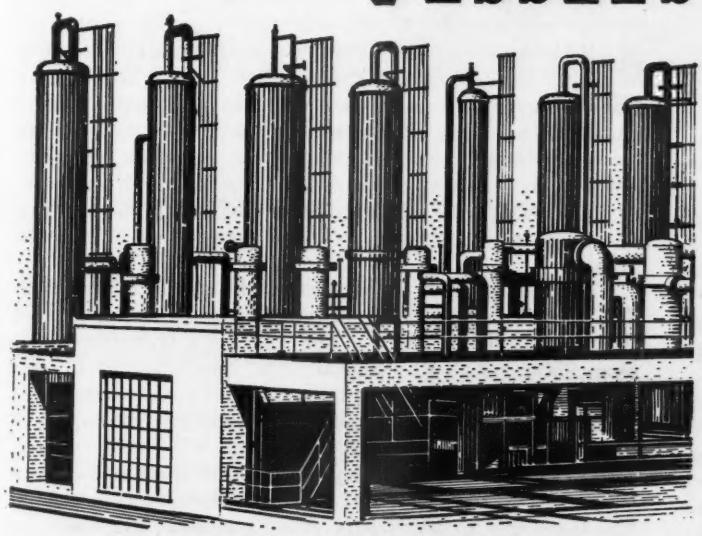
$$i(t) = A_c \cos [w_c t + \delta \sin w_m t], \tag{28}$$

where the signal to be modulated is

$$i_c = A_c \cos w_c t \tag{29}$$

(*Continued on page 27*)

VESSELS FOR VICTORY



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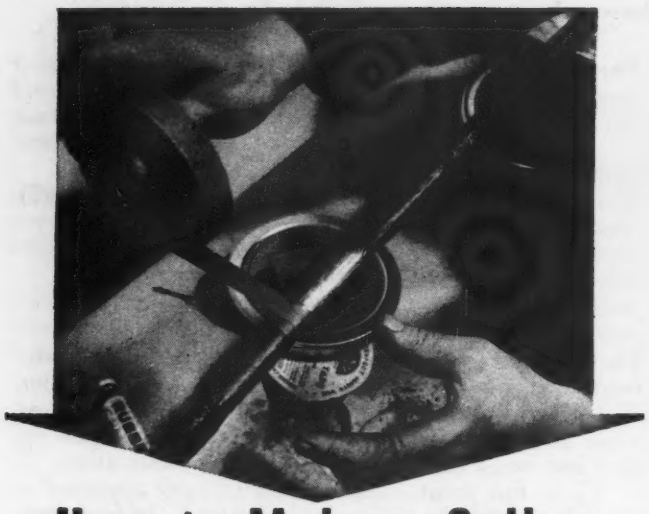

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AIRSHIP'S CHALLENGE

(*Continued from page 13*)

Recent Zeppelin practice has been to use duralumin, an aluminum alloy. In the future the use of magnesium is projected.

The skin of an airship is usually balloon cloth, which is fitted to the framework, and covered with aluminum paint to decrease the heating effect of the sun on the gas, which has a tendency to make the ship buoyant. An experimental blimp was built which used duralumin sheets .008 inch thick for the hull covering. The ship was apparently successful, but no more were built.

For motors, the airship usually has Diesels, as in the *Hindenburg* and *Macon*, or gasoline, as in the *Los Angeles*. The *Graf Zeppelin* had motors which burned Blau-gas, a gaseous fuel only slightly heavier than air. Thus consumption of fuel did not make the ship too buoyant. The number of motors varies from eight in the *Macon* to four in the *Hindenburg*.

The propellers of an airship are the reverse thrust type. It was for the airship that this type of propeller was pioneered. To provide better control, shorter turning radius, and a shorter braking length, the motors may be reversed. Most dirigibles have their motors in gondolas beneath the hull. On the *Macon* the engines were in the hull, and the eight propellers were ranged along the side, held in place by outriggers. The outriggers swiveled, allowing the propellers to thrust at any angle from horizontally forward to vertically upward. Because the propeller thrust could be reversed, this gave the ship a large degree of control and enabled it to rise and descend vertically. The ship rarely used the motors for ascending, but in landing the motors were often used to force the buoyant ship to the ground.

The tecbical improvements in the airship are paralleled closely by the improvements in airplanes. Stronger alloys will permit lighter, more durable frames, and will decrease weight. More powerful motors will increase the speed. Better streamlining will decrease drag. The use of a more efficient air-foil hull will increase the dynamic lift, and let a heavy ship fly. The development of an accurate all-weather altimeter has removed the cause of two serious crashes. The *R-101* and the *Akron* both crashed because their altimeters were at fault.

The commercial advantages of the airship are many. The most important is the large cargo that can be transported over long ranges. The *Hindenburg* had a cruising range of 8,000 miles with 72 passengers and 10 tons of cargo. The Boeing 314 Clipper has a range of 3,600 miles with 32 passengers and five tons of cargo. The speed of the Clipper is slightly more than double that of the *Hindenburg*. A proposed postwar Goodyear ship of 10,000,000 cubic feet would have a range of 6,000 miles with a payload of 42½ tons, or 2,000 miles with a payload of 200 tons. The Boeing *377*, the *Stratocruiser*, a commercial version of the Superfortress, has a range of 500 miles with a payload of 10 tons, or of 4,000 miles with seven tons. The *Hindenburg* charged 2¼ cents per pound per mile on the Friedrichshafen-Lakehurst run. The *377* would charge five cents per pound per mile on ranges up to 1,000 miles. The size and variety of the cargo on an airship can vary. In an airplane cargo size as well as weight is important. In an airship size is a minor qualification. The *Hindenburg* once carried a Trakehner horse from Friedrichshafen to Rio de Janeiro. Another time it carried an Opel town car over the same route. Airplanes too have flown by means of the *Hindenburg* to Europe, and to South America.

In the matter of accommodations, the airship is much superior to the airplane. The accommodations of an airship resemble those of an ocean liner. The *Hindenburg* had double staterooms for 72 people, promenade deck, salon equipped with a 112-pound piano, smoking lounge, and showers. No airplane has provided such accommodations for a like number of people. A proposed postwar dirigible would carry 228 people in a parlor car version, or 112 people in a stateroom version.

The initial cost of an airship is about $2,500,000. The *B-19* was insured for almost that much for its first thirty seconds of flight. The cost of a transport runs from $500,000 to $1,000,000. The operating costs of a dirigible are slightly more than those of an airplane operating over the same distance. The difference in capacity more than equalizes the discrepancy.

In the future the airship might be used again as a means of trans-Atlantic travel. Deutscher Zeppelin Reederei will undoubtedly try to reëstablish lines to New York and Rio de Janeiro, and a new firm known only as U. N. Airships, Inc. wants to operate service across the Atlantic to Scotland and on to Moscow and Istambul, as well as a South American line from Washington to Rio de Janeiro, Buenos Aires, Capetown and Karachi. Before the war, the Japanese government tried to acquire German airships to run a trans-Pacific route. U. N. Airships also would like to try that run. The Russians are reportedly interested in a Europe-Asia route, and the British are always interested in Empire communications. Certainly, given helium, and an even break, the airship should be able to prove herself.

THE HUM OF THE ARC *sounds the new note in construction*

The ear-splitting, nerve-shattering staccato sounds that formerly accompanied construction will not be the theme song of post-war building. Instead, the quietly efficient electric arc will weld together the steel skeletons of new structures. And, in so doing, it will save time, space and steel.

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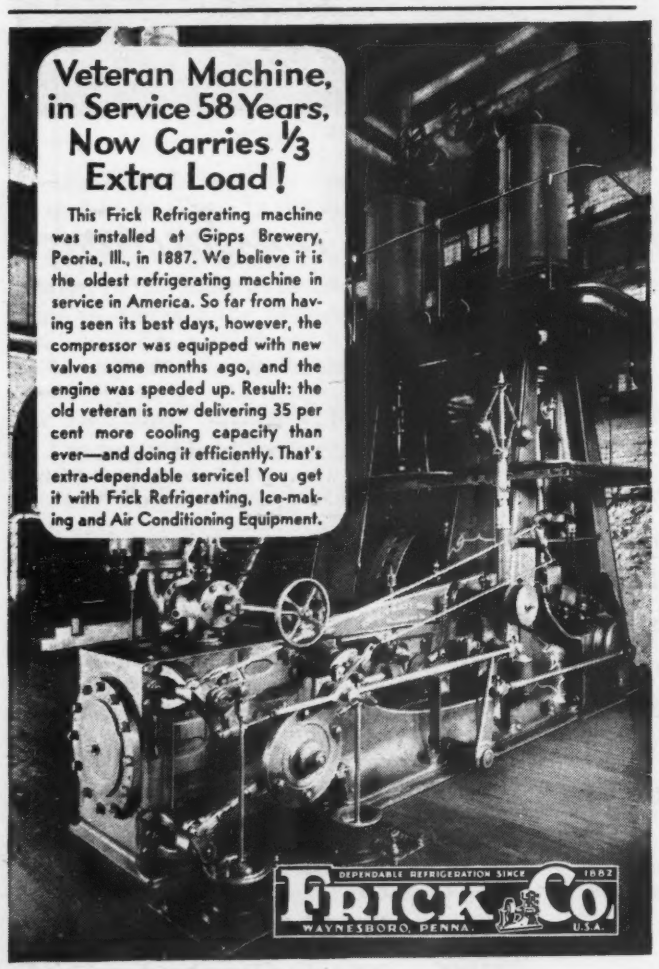
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Postwar Radar System Demonstrated as Valuable Navigation Aid

Radar which played a highly important role in the war was exhibited in its postwar form August 13 when General Electric demonstrated aboard a maritime training ship an "electronic navigator" that can detect through darkness, fog, and storm the position of any above-water obstacles, such as lighthouses, buoys, icebergs, other ships, and land, at distances up to thirty miles, depending upon the size and shape of the object.

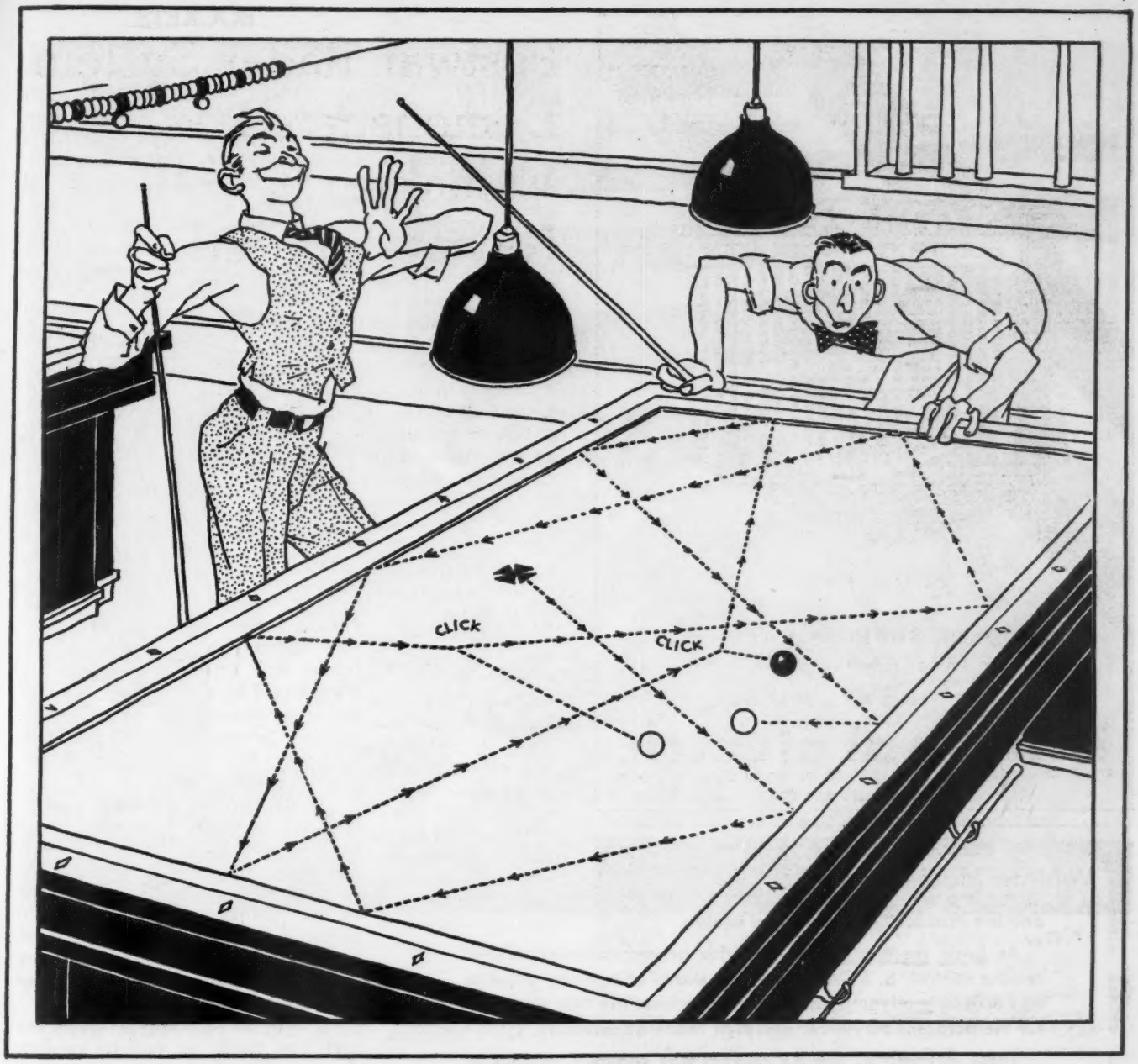
During the demonstration in the waters off Long Island, such objects as other ships, channel markers, lighthouses and land masses were shown in their relative positions, and both distance and bearing were automatically plotted on the face of the viewing screen in relation to the "American Mariner's" own course. The distance of objects from the ship was shown in true proportion, being measured by a series of concentric "marker rings" electronically super imposed on the picture screen. The measurement of distance so given is said to be accurate to one per cent.

Basis of the "electronic navigator," it was explained, is a rotating antenna, located on the top deck of the ship and analogous to a searchlight, in that it sends out beams to locate obstacles in the ship's path. The difference, of course, is that microwave beams from the radar antenna are capable of penetrating fog or any other atmospheric conditions without hindrance. Moreover, they are sent out as "pulses" or surges of extremely short duration and at a very rapid rate.

As the radar waves locate an obstacle in the surrounding waters, they bounce off and are scattered, no matter what material the object is. Some of these echoes — or scattered waves — will return to the rotating antenna, which also acts as the receiving antenna during the time intervals between the outgoing pulses. After being amplified, these echoes are made to appear as bright spots on the face of a cathode ray tube, which is somewhat similar to a television screen tube. The image thus formed gives the operator a "radar picture" of the obstacle, and the marker rings tell him how far away it is.

By controlling internal circuits, the operator may change the scale of the field to cover either a two, six, or thirty-mile radius. Thus, when a ship is sailing in the open sea, the operator will use the thirty-mile range until an object approaches to within six miles. Then, bu turning a knob on his radar set, he is immediately presented with a larger scale chart, the outer radius of which is six miles. For very close work another turn of the knob provides a two-mile radius chart on which objects may be observed down to about two hundred yards.

Radar waves sent out from the ship's antenna travel with the speed of light and therefore require only about a millionth of a second to make a round trip to an object two hundred yards away. Since the measure of distance to an obstacle is given with extreme accuracy by the marker circles, the system must be able to measure time down to one one-hundredth of a millionth of a second.



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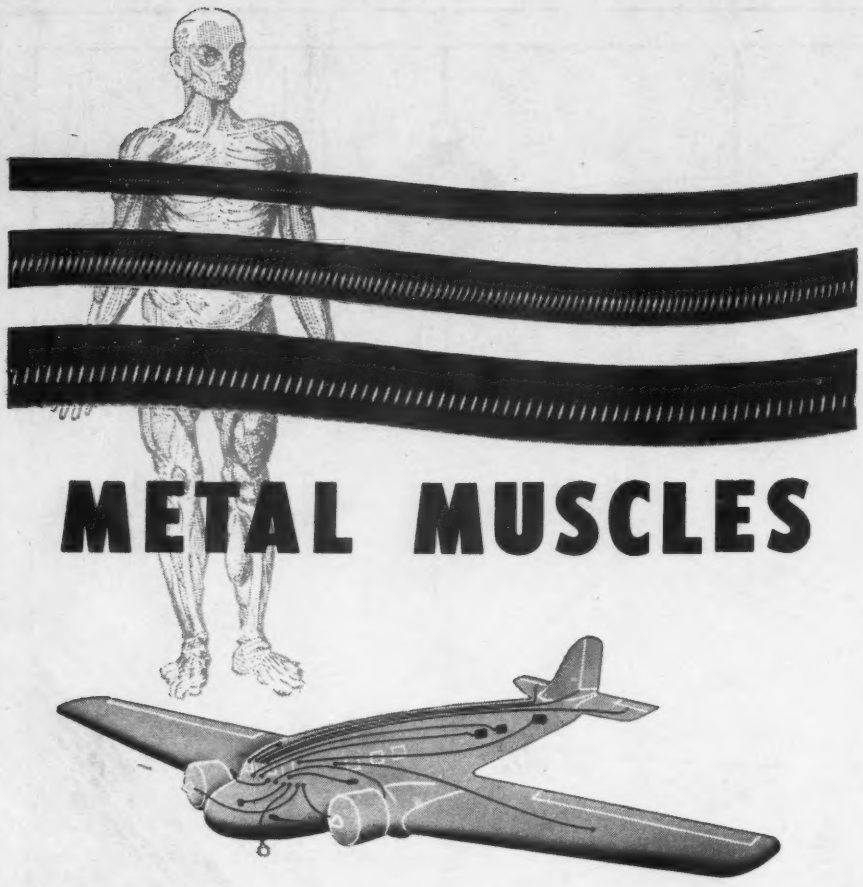

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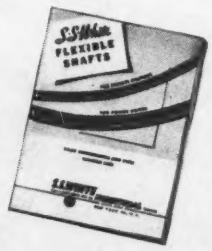
It gives the basic facts and technical data about flexible shafts and discusses their application for specific power drive and remote control requirements. You may have a free copy on request. Ask for Bulletin 4501 and please mention your college and course.



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ROCKETS

(*Continued from page 11*)

was slightly less than one-fourth inch. Upon subsequent tests with this same motor, thrusts were obtained up to twenty-five pounds, a figure which compares favorably with that obtained by theoretical considerations.

Meanwhile, the testing apparatus had been modified to allow for some needed improvements. Since the apparatus has undergone no major changes since this time, it will be of value to give a description of the set-up. Similar equipment was used by the other amateur organizations.

The equipment consists principally of two armored tanks, for fuel and oxidant, line connections to the motor, and devices for measuring line pressure, chamber pressure, and thrust. Backing pressure for the tanks is provided by the vaporization of the liquid oxygen and by a tank of compressed nitrogen. The system is usually operated at a pressure of three hundred pounds per square inch pressure. The pressure is regulated by a throttling valve on the nitrogen tank and several safety valves. Several views of the test apparatus are shown in the accompanying photographs.

At this stage in the Society's progress, a new problem arose, a very difficult one for all rocket experimenters. The intense heat of the burning gases melted the inner walls of the throat and nozzle of the motor. The trouble was aggravated by the eroding effect of the hot gases moving at high velocity over the internal surfaces of the motor.

In order to stop such erosion, resort was made to various cooling devices. The first attempt resulted in a motor very similar to the design shown in the diagram. The motor was all aluminum and had a cooling jacket surrounding the nozzle and the rear half of the combustion chamber. The liquid oxygen passed through this jacket before entering the combustion chamber. It was hoped that the extremely low temperature of the liquid oxygen, coupled with the good thermal conductivity of aluminum, would be sufficient to prevent breakdown of the nozzle walls.

A number of experiments were conducted with motors of this type. Finally, a steel motor was built that stood up satisfactorily with the aid of liquid oxygen cooling. This motor has undergone a number of tests successfully. It has a throat diameter of one-eighth inch and gives thrust up to ten pounds.

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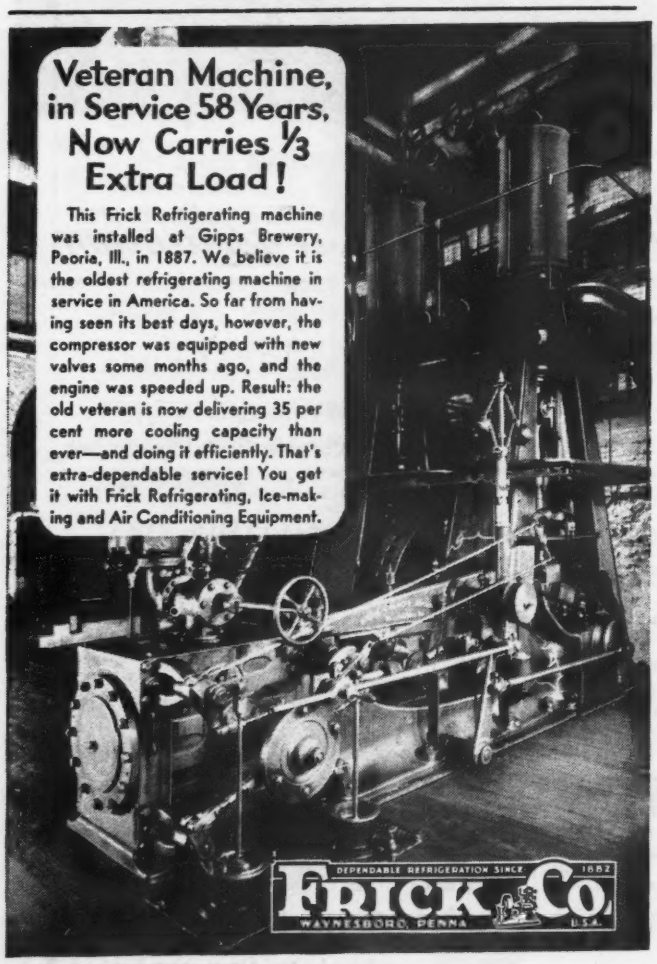
Veteran Machine, in Service 58 Years, Now Carries ⅓ Extra Load!
This Frick Refrigerating machine was installed at Gipps Brewery, Peoria, Ill., in 1887. We believe it is the oldest refrigerating machine in service in America. So far from having seen its best days, however, the compressor was equipped with new valves some months ago, and the engine was speeded up. Result: the old veteran is now delivering 35 per cent more cooling capacity than ever—and doing it efficiently. That's extra-dependable service! You get it with Frick Refrigerating, Ice-making and Air Conditioning Equipment.
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Postwar Radar System Demonstrated as Valuable Navigation Aid

Radar which played a highly important role in the war was exhibited in its postwar form August 13 when General Electric demonstrated aboard a maritime training ship an "electronic navigator" that can detect through darkness, fog, and storm the position of any above-water obstacles, such as lighthouses, buoys, icebergs, other ships, and land, at distances up to thirty miles, depending upon the size and shape of the object.

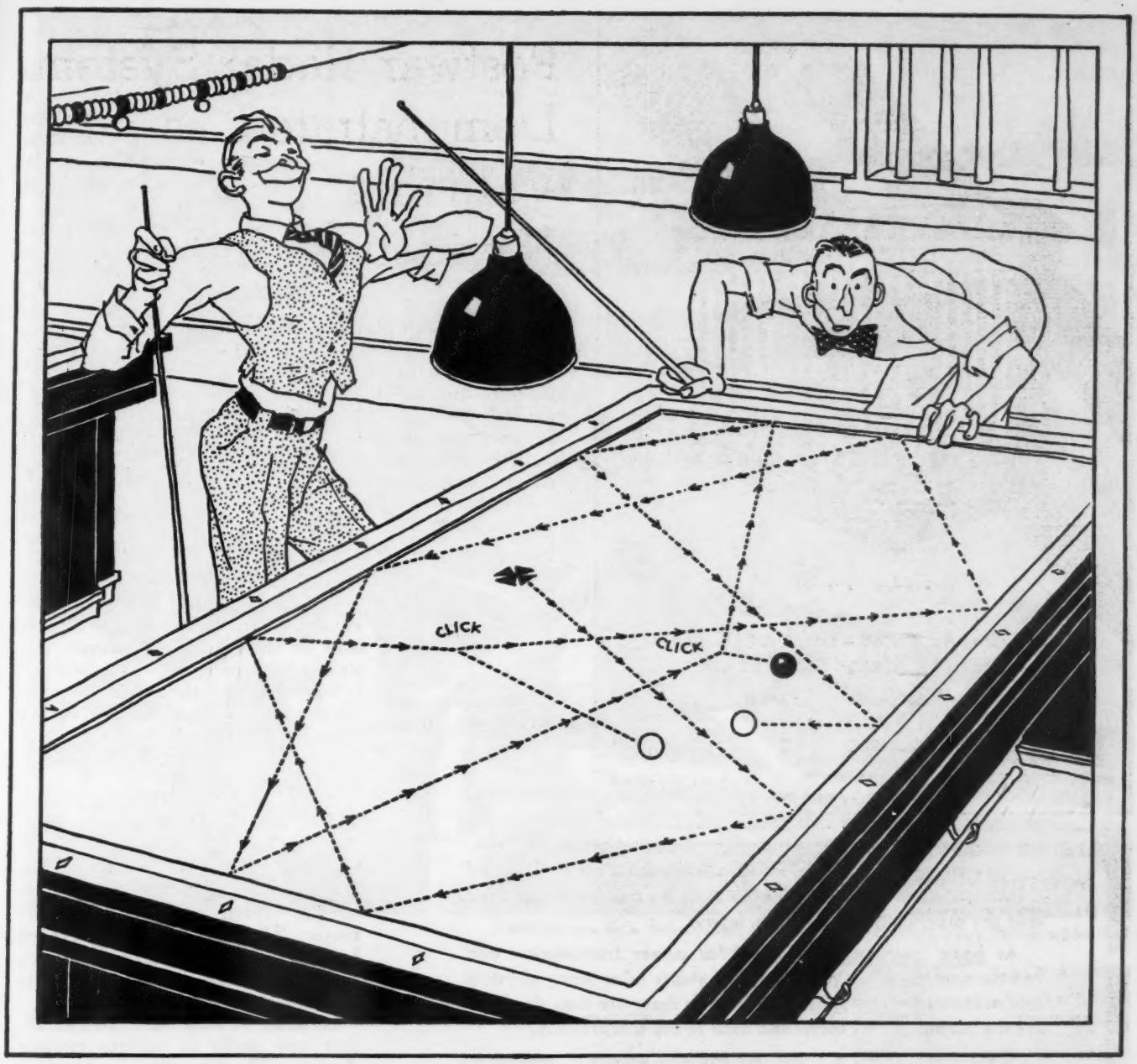
During the demonstration in the waters off Long Island, such objects as other ships, channel markers, lighthouses and land masses were shown in their relative positions, and both distance and bearing were automatically plotted on the face of the viewing screen in relation to the "American Mariner's" own course. The distance of objects from the ship was shown in true proportion, being measured by a series of concentric "marker rings" electronically super imposed on the picture screen. The measurement of distance so given is said to be accurate to one per cent.

Basis of the "electronic navigator," it was explained, is a rotating antenna, located on the top deck of the ship and analogous to a searchlight, in that it sends out beams to locate obstacles in the ship's path. The difference, of course, is that microwave beams from the radar antenna are capable of penetrating fog or any other atmospheric conditions without hindrance. Moreover, they are sent out as "pulses" or surges of extremely short duration and at a very rapid rate.

As the radar waves locate an obstacle in the surrounding waters, they bounce off and are scattered, no matter what material the object is. Some of these echoes — or scattered waves — will return to the rotating antenna, which also acts as the receiving antenna during the time intervals between the outgoing pulses. After being amplified, these echoes are made to appear as bright spots on the face of a cathode ray tube, which is somewhat similar to a television screen tube. The image thus formed gives the operator a "radar picture" of the obstacle, and the marker rings tell him how far away it is.

By controlling internal circuits, the operator may change the scale of the field to cover either a two, six, or thirty-mile radius. Thus, when a ship is sailing in the open sea, the operator will use the thirty-mile range until an object approaches to within six miles. Then, bu turning a knob on his radar set, he is immediately presented with a larger scale chart, the outer radius of which is six miles. For very close work another turn of the knob provides a two-mile radius chart on which objects may be observed down to about two hundred yards.

Radar waves sent out from the ship's antenna travel with the speed of light and therefore require only about a millionth of a second to make a round trip to an object two hundred yards away. Since the measure of distance to an obstacle is given with extreme accuracy by the marker circles, the system must be able to measure time down to one one-hundredth of a millionth of a second.



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. . . and this triumphant gentleman profits by his skilled application of that fundamental fact.

That same fact, applied in New Departure *Ball* Bearings, brings new efficiency—and profit—to industry. Industry which *must* "keep 'em rolling"—(and nothing rolls like a ball).

Today, Industry is faced with new and mounting problems of higher speeds, heavier loads and greater and greater precision. *Ball* bearings carry the loads on free-rolling steel balls—*making possible* higher speeds, heavier loads and greater precision.

Yes, in millions of applications, New Departure Ball Bearings are proving their *unique* fitness for the new scheme of things mechanical.

There is more for you in New Departure Ball Bearings than steel and precision. Advanced engineering and a desire to serve are tangible plus values.

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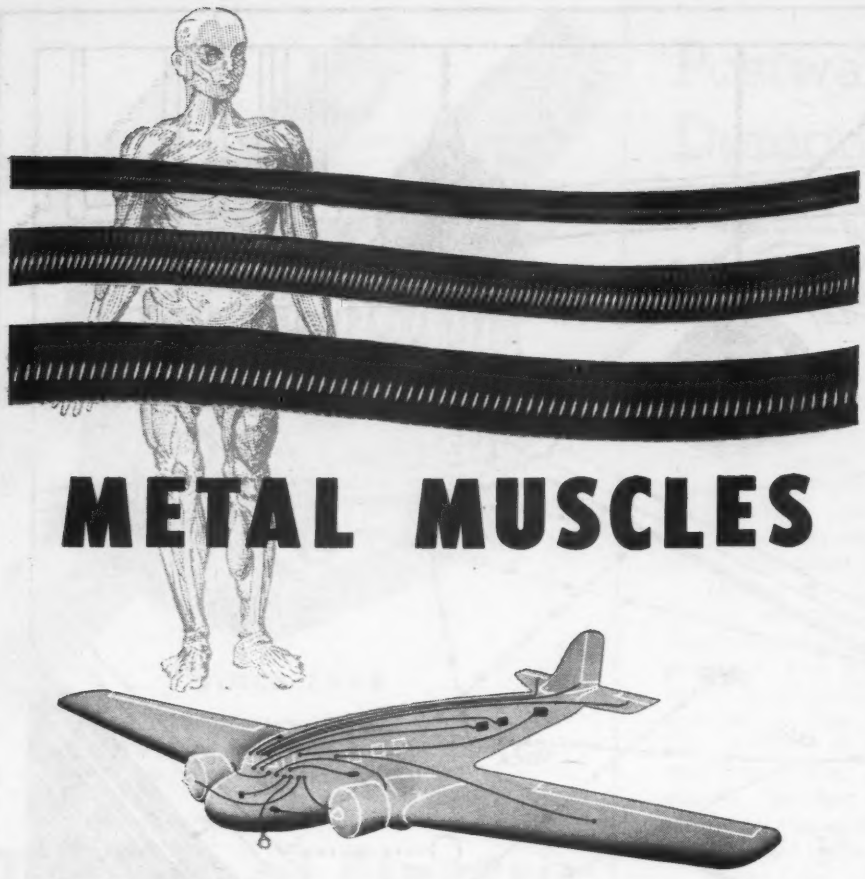


METAL MUSCLES

What muscles are to human bodies, S. S. White flexible shafts are to mechanical bodies. Like muscles, S. S. White flexible shafts are flexible elements for transmitting rotational power and control to moving parts—metal muscles for motivating all kinds of driven and controlled mechanisms—muscles that never get tired and are practically immune from injury.

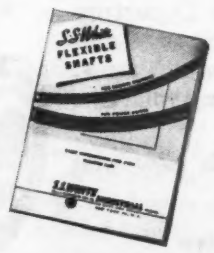
As *basic mechanical elements* for power transmission and remote control, S. S. White flexible shafts offer many physical and economic advantages. Chief among these are their simplicity for the purposes they serve and their ready adaptability.

These advantages are the reasons why annually, millions of feet of S. S. White flexible shafts go into aircraft, motor vehicles, machinery, portable tools, radio and electronic equipment and a wide variety of other products.

As an engineer you will find it well worth while to familiarize yourself with the range and scope and possibilities of these *metal muscles* for power transmission and remote control.

THIS BULLETIN WILL HELP YOU

It gives the basic facts and technical data about flexible shafts and discusses their application for specific power drive and remote control requirements. You may have a free copy on request. Ask for Bulletin 4501 and please mention your college and course.



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ROCKETS

(*Continued from page 11*)

was slightly less than one-fourth inch. Upon subsequent tests with this same motor, thrusts were obtained up to twenty-five pounds, a figure which compares favorably with that obtained by theoretical considerations.

Meanwhile, the testing apparatus had been modified to allow for some needed improvements. Since the apparatus has undergone no major changes since this time, it will be of value to give a description of the set-up. Similar equipment was used by the other amateur organizations.

The equipment consists principally of two armored tanks, for fuel and oxidant, line connections to the motor, and devices for measuring line pressure, chamber pressure, and thrust. Backing pressure for the tanks is provided by the vaporization of the liquid oxygen and by a tank of compressed nitrogen. The system is usually operated at a pressure of three hundred pounds per square inch pressure. The pressure is regulated by a throttling valve on the nitrogen tank and several safety valves. Several views of the test apparatus are shown in the accompanying photographs.

At this stage in the Society's progress, a new problem arose, a very difficult one for all rocket experimenters. The intense heat of the burning gases melted the inner walls of the throat and nozzle of the motor. The trouble was aggravated by the eroding effect of the hot gases moving at high velocity over the internal surfaces of the motor.

In order to stop such erosion, resort was made to various cooling devices. The first attempt resulted in a motor very similar to the design shown in the diagram. The motor was all aluminum and had a cooling jacket surrounding the nozzle and the rear half of the combustion chamber. The liquid oxygen passed through this jacket before entering the combustion chamber. It was hoped that the extremely low temperature of the liquid oxygen, coupled with the good thermal conductivity of aluminum, would be sufficient to prevent breakdown of the nozzle walls.

A number of experiments were conducted with motors of this type. Finally, a steel motor was built that stood up satisfactorily with the aid of liquid oxygen cooling. This motor has undergone a number of tests successfully. It has a throat diameter of one-eighth inch and gives thrust up to ten pounds.

With the new RCA lifeboat radio, shipwrecks need no longer take a terrible toll of lives.

A two-way radiophone—for lifeboats!

Here's when a telephone comes in rather handy . . . when you can "get your party" and hear "We'll be there to get you in a couple of hours!"

With the new RCA compact lifeboat radio, that's exactly what happens. A kite, or a balloon, takes the antenna up 300 feet.

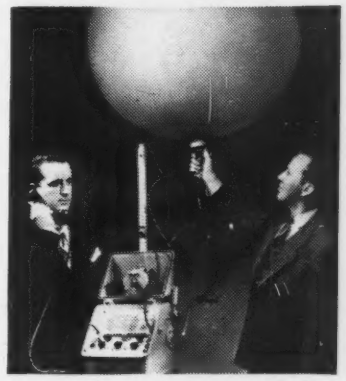
Turn the power-generating cranks and out goes an SOS—along with a direction-finder beam so shore stations can figure your exact location.

But even more amazing, shipwrecked mariners can talk with the men on their way to the rescue. They can "pick up" ships, airplanes, and that wonderful place called "land"—even if it's 1000 miles away!

Endless research, such as went into developing this lifeboat radio, goes into all RCA products.

And when you buy an RCA Victor radio, or television set or Victrola, you enjoy a unique pride of ownership in knowing that you possess one of the finest instruments of its kind that science has achieved.

Radio Corporation of America, RCA Building, Radio City, New York 20. • *Listen to The RCA Show, Sundays, 4:30 P.M., E.W.T., over the NBC Network.*



Joseph McDonald and Donald Kolb (holding balloon) are the Radiomarine engineers who developed this lifeboat radio. Here is the balloon that is inflated with helium and carries the antenna as high as 300 feet into the air.

RCA **RADIO CORPORATION of AMERICA**

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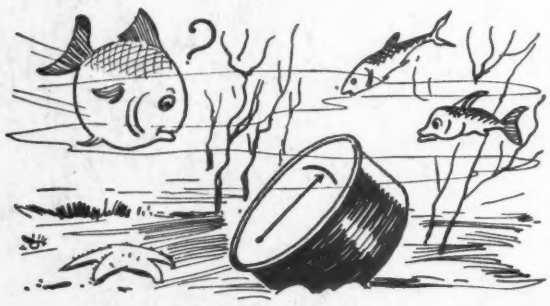
GE Campus News

RESEARCH AND ENGINEERING KEEP GENERAL ELECTRIC YEARS AHEAD

TANK WRECKER

THE trail of tank wreckage from Normandy to Berlin is evidence of a super shell's effectiveness. It was one of the potent weapons necessary to drive the enemy back to Berlin for keeps.

The shell's core is cemented tungsten carbide, improved by G-E research and manufactured by the Carboloy Company, G-E affiliate. The material is second to diamonds in hardness, and is commonly used for the tips of cutting tools and wear-resistant dies. Projectiles using these cores weigh less than ordinary shells, because of their light-weight housings, and so have higher velocity. They often stopped German Tigers with a single shot at ranges up to 3000 yards.



SAFE FROM PUNISHMENT

MORTAL enemies of all electric instruments are humidity, water, dust, fungus, and the like. Contact with any of these makes the instruments corrode. Their parts swell and burst, and sometimes their pointers fall off.

General Electric has developed a method for protecting instruments from such punishment—hermetically sealing them. Now dust storms can rage, or the temperature can change from 67 degrees below to 185 above without causing any change in their performance. Hermetically sealed instruments, while being tested, have even worked submerged in sixty feet of water.

FROM ONE SHIP TO ANOTHER

COLORFUL signaling will be in order on Navy vessels from now on. With any one of three special colored lenses—or clear glass—to go on over the shutter, a new G-E searchlight can send code messages in up to four different colors.

Four messages at once can go out to the same ship without confusing those on the receiving end. Cylinder-shaped hoods, each with a different colored lens, fit over each of four searchlights. The hoods tunnel and direct the narrowed-down beams of light, making the messages impossible to intercept except by those in a direct line of vision. *General Electric Company, Schenectady 5, New York.*

Hear the G-E radio programs: "The G-E All-girl Orchestra," Sunday 10:00 p.m. EWT, NBC—"The World Today" news, Monday through Friday, 6:45 p.m. EWT, CBS—"The G-E House Party" Monday through Friday 4:00 p.m. EWT, CBS.

The best investment in the world is in this country's future. Keep all the Bonds you Buy.

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